Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

JULY, 1951

AUG 2 1951

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WEAN STEEL MILL *Equipment is*

WORLD WIDE

The WEAN ENGINEERING COMPANY, INC.

WARREN, OHIO

SPECIALISTS IN SHEET, TIN and STRIP MILL EQUIPMENT

the Crane SAFETY LIMIT STOP

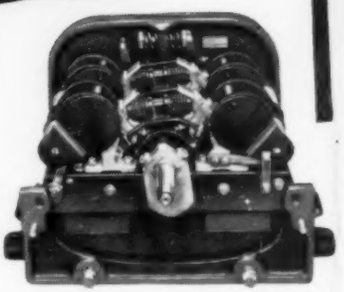
...THAT SET *New Standards of Performance*

There probably has never been a crane safety limit stop switch that so completely embodies *all* the wants of steel mill engineers as the Type P-100 Cutler-Hammer Safety Limit Stop, for 41 to 100 H.P. installations or the P-200 Safety Limit Stop for 101 to 200 H.P. installations. This is demonstrated by the fact that time after time engineers have taken one look at it and said: "That is what I want".

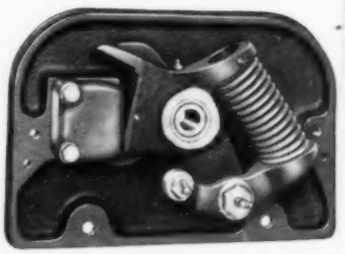
C-H Type P-100 100 H. P.

C-H Type P-200 200 H. P.

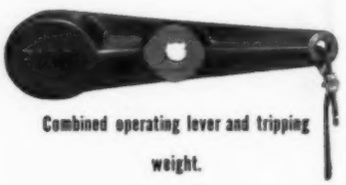
The photographs shown here tell their own story . . . a story of simple design . . . of rugged construction . . . of dependable, unfailing operation. The Cutler-Hammer Crane Safety Limit Stop has set new standards of performance every time, every way. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wis. *Associate*: Canadian Cutler-Hammer, Ltd., Toronto.



Movable contacts and arc shields in position. (Operating head removed).



Inside view of removable head, showing snap action mechanism.



Combined operating lever and tripping weight.

CHECK THESE OUTSTANDING FEATURES

Low headroom required.

Totally enclosed tripping mechanism—can't be made inoperative by rain, snow, ice, dirt or falling objects.

Slate contact supports, slotted, provide ample insulation to ground.

Snap action make and break—hammer blow of tripping is absorbed by spring bumper.

Cover strong enough to support a man's weight.

Rigid one-piece construction of operating lever and tripping weight.

Only one hanging weight, and that has double guides, adjustable to meet any practical installation condition, to prevent fouling the weight by the hoisting cables.

The snap action is obtained from a compression spring, with a very low unit stress. Even if it should break, the mechanism will operate because spring is held in place by an inside guide.

Ball bearings, with means for lubricating by standard grease fittings, used throughout.

Flexible leads brought out for ease of installation.

Gasketed cover to keep out dirt.

Mounting interchangeable with old style P-2.

Blowouts latched in place when mounted in position (3) or (4).

Cover chained to case to prevent dropping to ground during inspection.

(Below) Operating lever can be mounted in any of 4 quadrants.

CUTLER-HAMMER
MOTOR CONTROL
C-H

IRON AND STEEL ENGINEER; published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., entered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania, under Act of Congress, March 3, 1879. $7.50 per year in United States and Canada, $10.00 foreign countries. Volume 28, No. 7

Tech

R v.28 Jul.-Dec. 1951

AETNA-STANDARD makes drawbenches for drawing ferrous or non-ferrous tubes and bars . . . . . .

in diameters from 1/8" to 16" —
pulling capacities, 2,500 to 300,000 pounds

aetna-standard

THE AETNA-STANDARD ENGINEERING COMPANY . YOUNGSTOWN, OHIO

Plants in Warren, Ohio . Ellwood City, Pennsylvania

ASSOCIATED COMPANIES

Head Wrightson Machine Company, Ltd., Middlesbrough, England—Great Britain, Finland, Sweden, Norway, Denmark, Union of South Africa, Northern and Southern Rhodesia.

Aetna-Standard Engineering Company, Ltd., Toronto, Ontario, Canada.

M. Castellvi, Inc., New York, N. Y.—Mexico, Central and South America.

Societe de Constructions de Montbard, Paris, France—France, Belgium, Holland, Luxembourg, Switzerland.

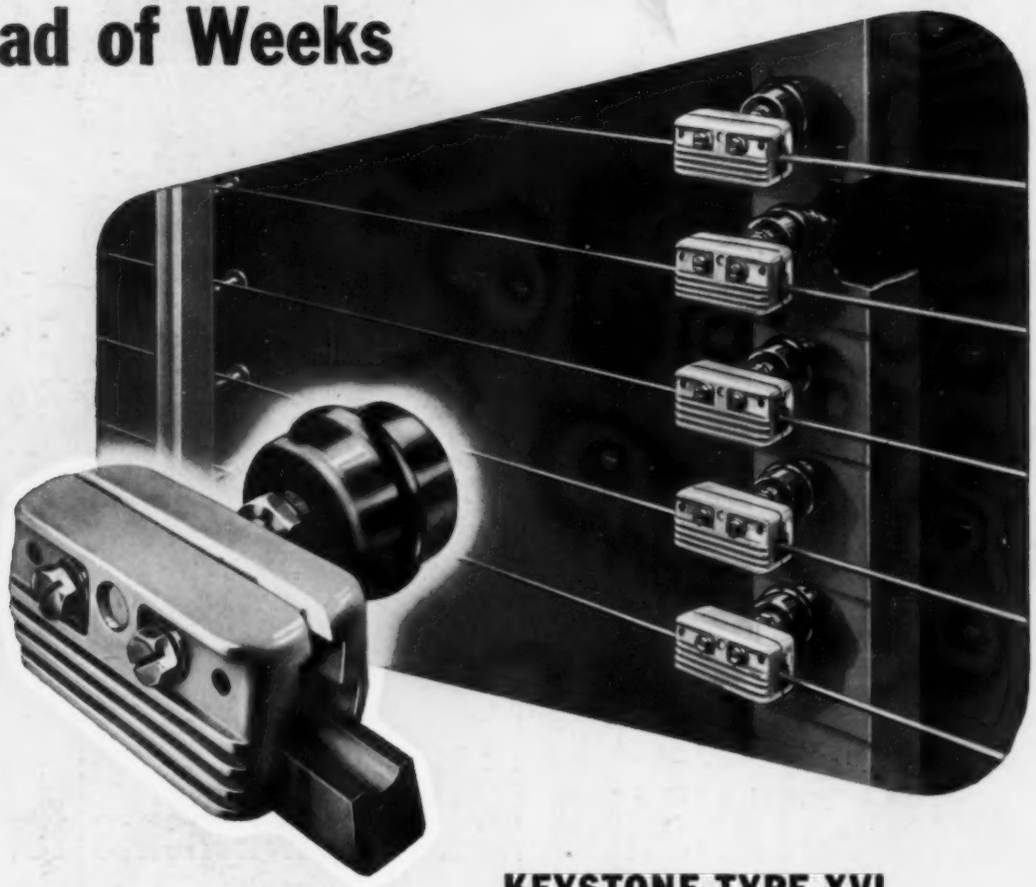
Compagnia Italiana Forme Acciaio, Milano, Italy—Italy.

Aetna-Japan Company, Ltd., Tokyo, Japan—Japan.

Hale & Kullgren, Inc., Akron, Ohio—Representative for the Rubber Industry.

Designers and Builders to the Ferrous, Non-Ferrous, Leather and Rubber Industries

NOW Crane Collectors Last *MONTHS*... Instead of Weeks



KEYSTONE TYPE XVI

COLLECTORS CUT DOWN TIME, WORK STOPPAGE, AND COSTS

A large New Jersey corporation had a serious current collector replacement problem on its foundry crane. Ordinary collectors failed after one week's service! Production stopped, but furnaces still burned, as workers climbed up to make replacements.

Loss in production and labor time prompted the company to find a better current collector. Keystone Type XVI Collectors were recommended and installed. Now collectors *last months* before replacement is required! Production is up with a minimum loss of labor time.

Some Keystone Type XVI Collectors have lasted 25 times longer than ordinary collectors. Features include, inexpensive carbon contact easily removed by backing out two set screws. Large contact area is non-arcing, noiseless, self-cleaning and self-lubricating. Provides constant contact, longer life. Housing consists of two aluminum castings with large radiating fins to provide lower operating temperatures. For all sizes of trolley wires up to 4/0 incl.

If you have a similar current collecting problem in your plant, find out about Keystone Type XVI Collectors. Write us today for latest, illustrated folder on Keystone electrical products.

ELECTRIC SERVICE MANUFACTURING CO.

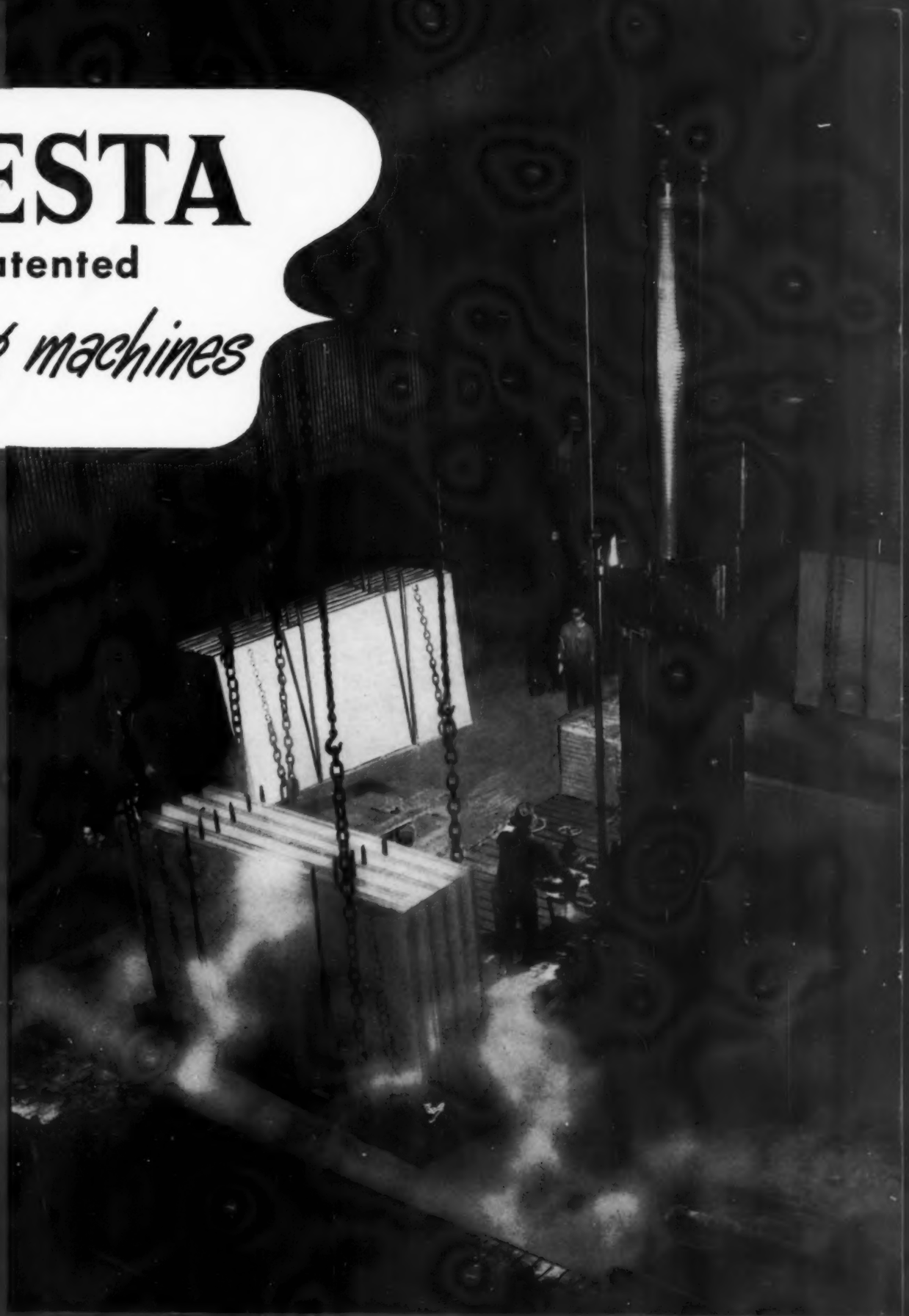
PHILADELPHIA 32, PENNA.

Manufacturers of complete line of insulator supports for rail and wire conductors and current collection devices.

MESTA

patented

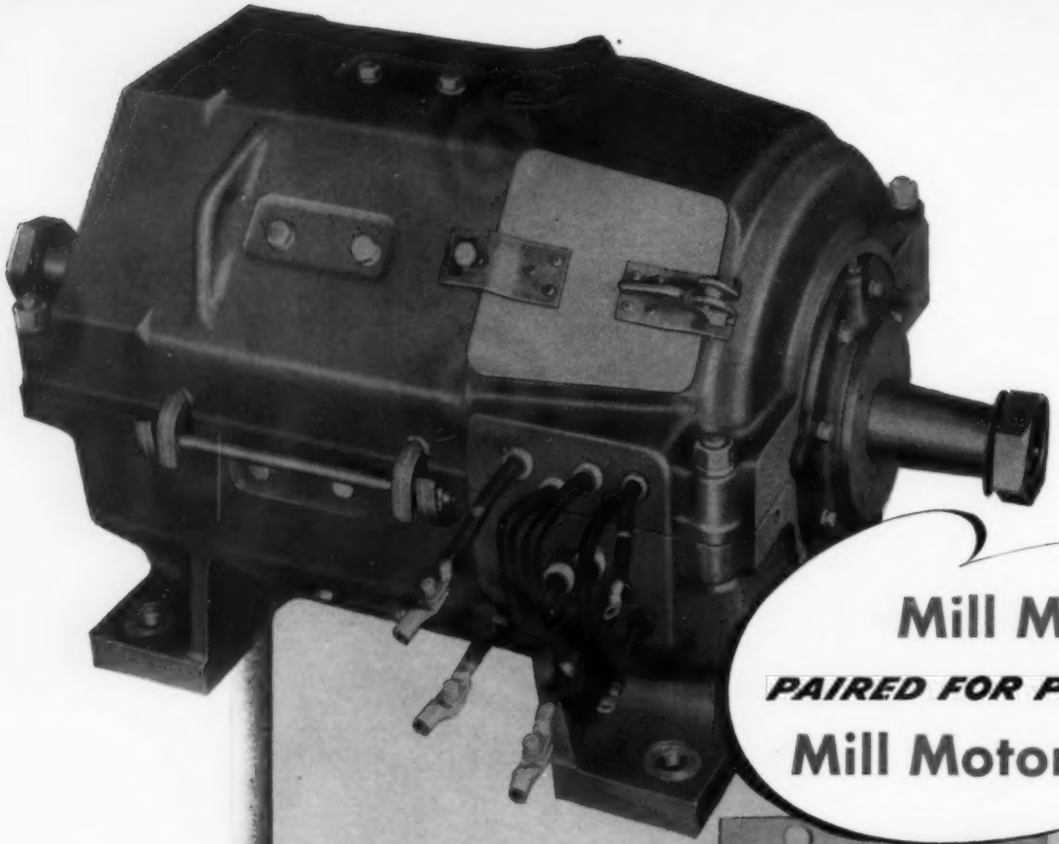
pickling machines



DESIGNERS AND BUILDERS OF COMPLETE STEEL PLANTS

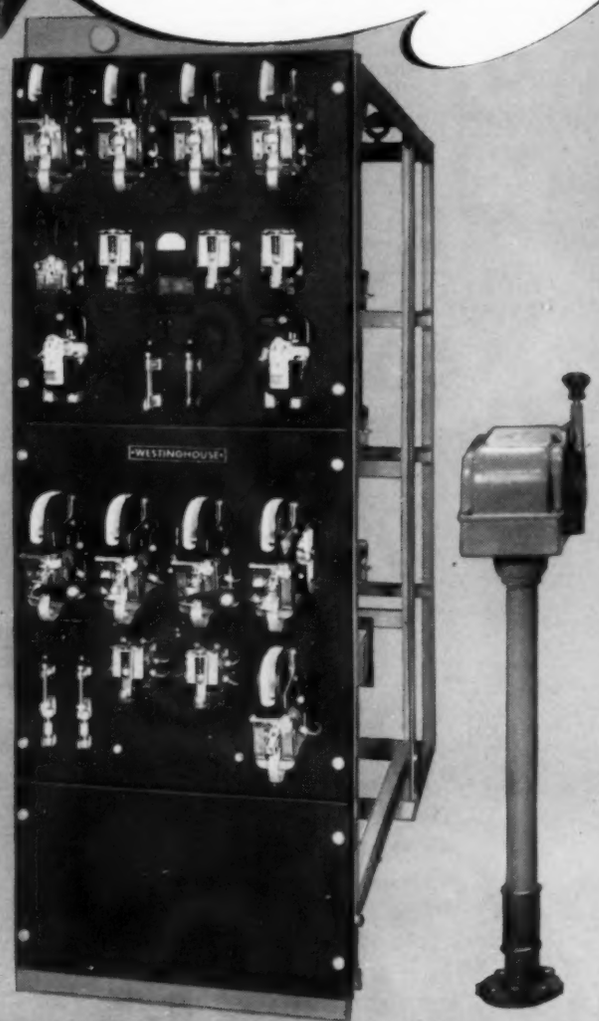
MESTA MACHINE COMPANY

PITTSBURGH, PA.



Mill Motor
PAIRED FOR PRODUCTION
Mill Motor Control

600 Series Mill Motor



Typical 9500
Line Controller, Type M
Contactors and Type SM
Master Switch

Rugged!

cut mill down time with this team

Certainly in a mill, where down time costs add up fast, the ability of equipment to stand up to rugged continuous duty is of paramount importance. That's why you'll find this combination hard to beat. They are rugged . . . made together to work together. Each incorporates the latest design features to keep production lines rolling.

Take the motor for example. The high starting torque of this new 600 series mill motor is ideal for high inertia loads . . . proved commutation . . . high rated efficiency assures maximum performance under tough service conditions . . . simplified construction makes servicing and maintenance easy. It is a brand-new motor with a new kind of performance built for today's tougher jobs.

Controllers, too, are built to assure new dependability. Main contactors are the new Type M with knife-edge, trouble-free bearings . . . with exclusive Quick-Quench arc boxes which greatly increase contact life. Overload relays are the dual thermal instantaneous type. Accelerating relays are the time-proved inductive time delay Type AZ.

The third part of this control team is the rugged Type SM master switch. Easy to operate, yet with a definite "feel" for each operating point of position, the switches are available with 2 to 6 speed control.

Together, these three offer a new kind of dependability. Get the facts on all three. Ask your nearby Westinghouse representative for a copy of the new booklet B-4730, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-21647

YOU CAN BE SURE.. IF IT'S

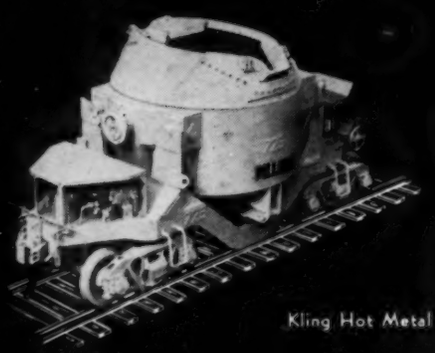
Westinghouse

MILL MOTORS AND CONTROLS

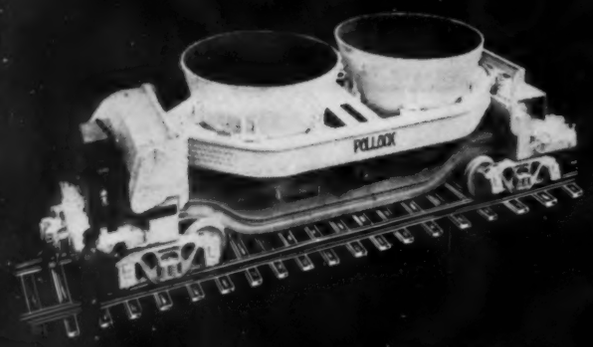
BLAST FURNACE CARS FOR THE IRON AND STEEL INDUSTRY . . .

POLLOCK

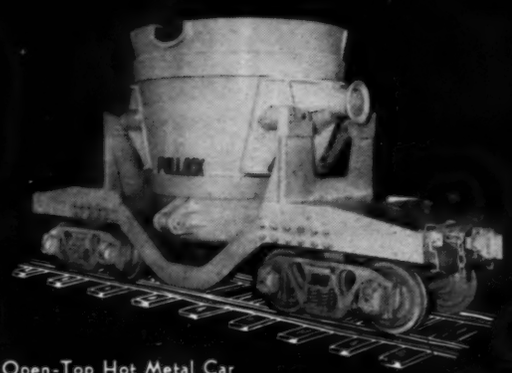
BUILDS ALL TYPES



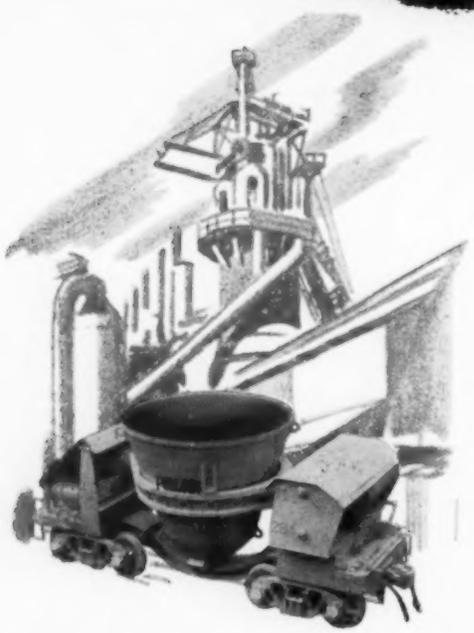
Kling Hot Metal Car



Double Pot Cinder Car



Open-Top Hot Metal Car



● **POLLOCK hot metal cars** are equipped with demountable ladles, standard or "tailor-made" to meet your individual needs—in any capacity up to 100 tons—and these can be made even larger, depending on railroad clearances. The car bodies are of welded steel construction, either all-welded in one piece, or with end and side frames bolted together to save space in shipping. Both Kling and Open-Top types can be supplied for long pouring or short pouring.

POLLOCK cinder cars, made for air, steam, or electric operation, are sturdily built of all-rolled welded steel construction, with pots of capacities up to 400 cubic feet each. Operating equipment can be arranged to dump from either side, and trucks have A. A. R. standard wheels, axles, bearing brasses and springs. Special end-thrust bearings or roller bearings of your choice can be provided.

Let Pollock's expert engineers make a study of your hot metal and cinder handling requirements, and recommend the blast furnace car equipment best suited to your plant.

POLLOCK

THE WILLIAM B. POLLOCK COMPANY

YOUNGSTOWN · OHIO

STEEL PLATE CONSTRUCTION · ENGINEERS · FABRICATORS · ERECTORS

BLAST FURNACES · HOT METAL CARS AND LADLES · CINDER AND SLAG CARS · INGOT MOULD CARS · CHARGING BOX CARS · WELDED OPEN HEARTH LADLES

In its New Joliet Plant
and 128 Acre Peoria Plant

CATERPILLAR

World's largest makers of Diesel road-building equipment

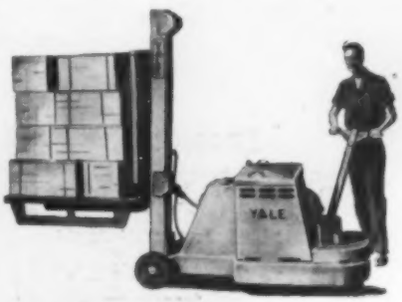
MOVES, LIFTS AND STACKS MATERIALS WITH YALE!

PRODUCTION is rolling at a record pace here in "Caterpillar's" Peoria and new Joliet plants—but "Caterpillar" quality stays as high as ever.

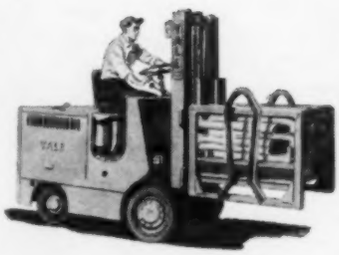
It's a staggering job putting these big "Cat" products together on a volume basis—one that requires tremendous tonnages of materials to be stored and moved through these vast plants every day.

That's where YALE comes in.

With YALE Fork Trucks, Crane Trucks and Hoists on the job "Caterpillar" gets valuable help in stretching storage facilities to match increased output, in keeping production lines humming, production costs down.



In your plant, too, this versatile, hard working Materials Handling Equipment can turn out an amazing day's work—safely, and with important savings to you in space, man hours, and money. Just send us the coupon below today and we'll show you exactly how to get these results.



YALE is the registered trade mark of The Yale & Towne Manufacturing Company

Send for all the facts today!

YALE & TOWNE

Philadelphia 15, Pa.

In Canada write The Yale & Towne Manufacturing Company, St. Catharines, Ontario

The Yale & Towne Manufacturing Co., Dept. 347
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I am interested in cutting my materials handling costs.

_____ *Please have your local representative call on me.*

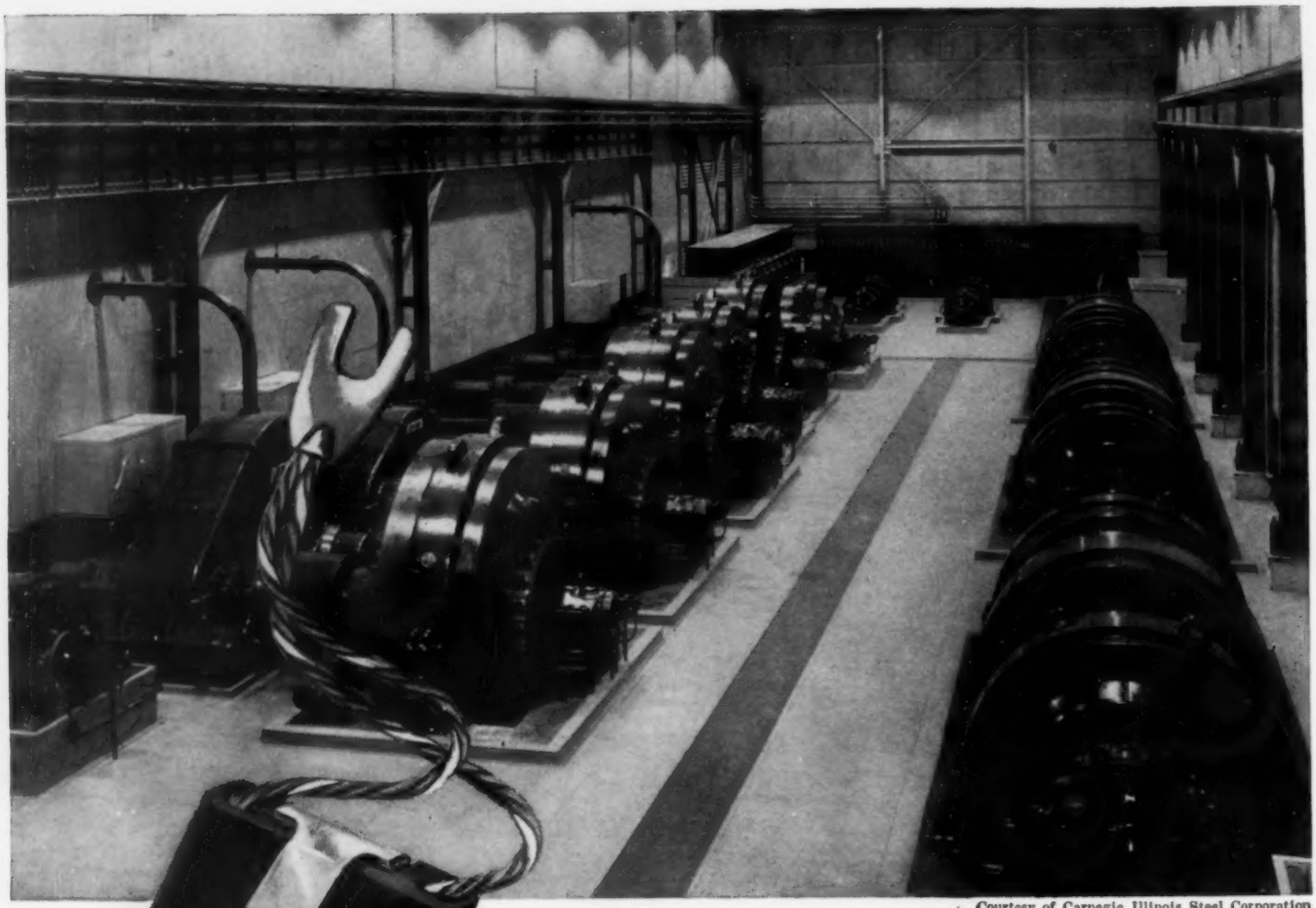
_____ *Please send me detailed literature.*

NAME_____

COMPANY_____

STREET_____

CITY_____ STATE_____



Courtesy of Carnegie Illinois Steel Corporation

KEEP PRODUCTION ROLLING WITH SA35!

The NATIONAL TRADE-MARK standardized brush for main-drive motors

Main-drive motors and generators are the most important machines in the mill. If one of them fails, production stops dead. Tons of steel may be held up. It doesn't pay to take chances with the brushes on this vital equipment.

Here's why "National" SA-Series grades lead the field on main-drive equipment:

- Complete dependability, proved in service for many years
- Closely controlled commutation factor
- Minimum commutator wear
- Long life
- Low flat price, for one box or 10,000 boxes
- Unequalled uniformity

STANDARDIZED BRUSHES FOR MAIN-DRIVE MOTORS AND GENERATORS

NC NUMBER	SPECIFICATIONS	APPLICATIONS
NC 12-5610	2½ x 1¾ x ⅜ Grade SA-35	For Westinghouse Tandem Holders
NC 16-5603	2½ x 1¾ x ½ Grade SA-35	For Westinghouse Tandem Holders
NC 12-4802	2¼ x 1½ x ⅜ Grade SA-35	For "Toe-to-Toe" Holders
NC 16-4804	2¼ x 1½ x ½ Grade SA-35	For "Toe-to-Toe" Holders

Order by NC Number

FOR COMPLETE INFORMATION on National Carbon's brush standardization program and the advantages it offers, write to National Carbon Company, A Division of Union Carbide and Carbon Corporation, Dept. IS.

The term "National" and the Three Pyramids Device are registered trade-marks of Union Carbide and Carbon Corporation

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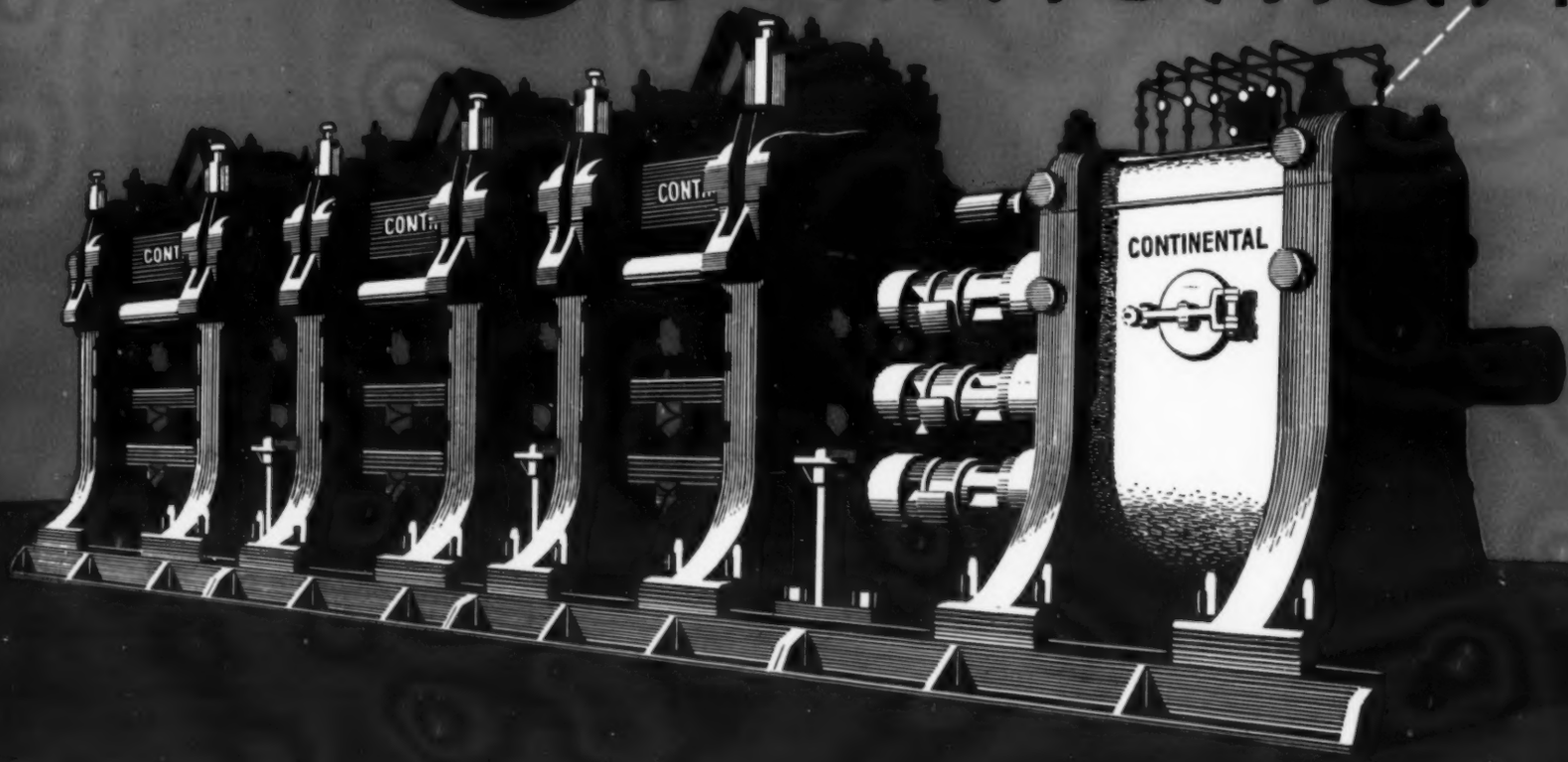
IN CANADA: National Carbon Limited, Montreal, Toronto, Winnipeg

Continental

for STRUCTURAL and BAR MILLS



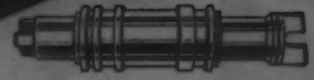
Designed and built by Continental with full complement of auxiliary mill equipment.

Continental

FOUNDRY & MACHINE CO.

CHICAGO . PITTSBURGH

Plants at: E. Chicago, Ind.; Wheeling, W. Va.; Pittsburgh, Pa.

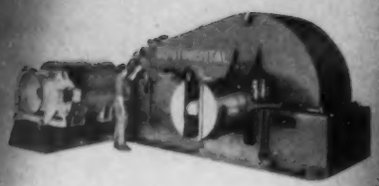


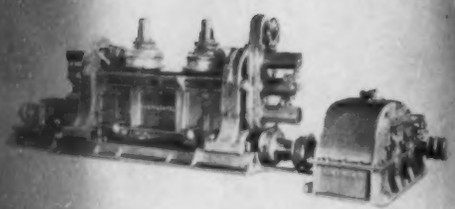
ROLLS

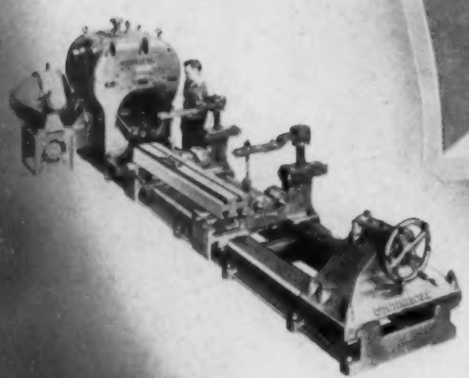
IRON, ALLOY IRON AND STEEL

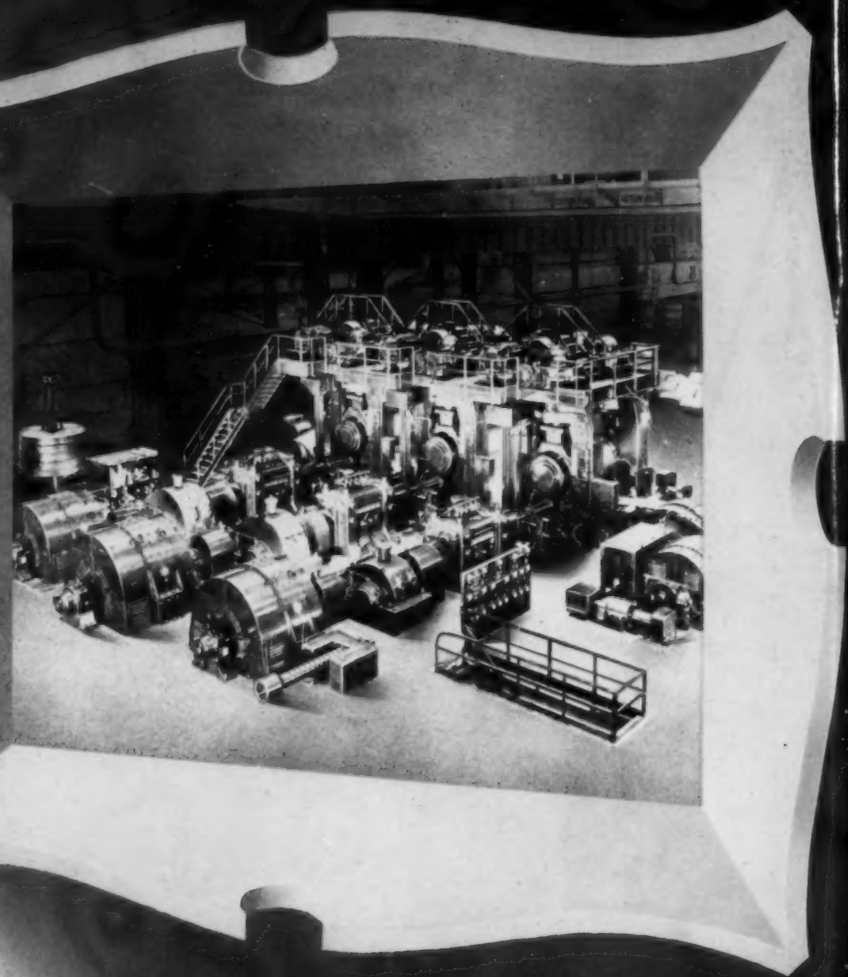
STEEL CASTINGS

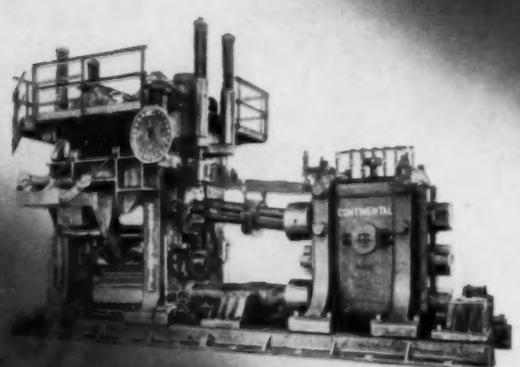
20 TO 250,000 POUNDS







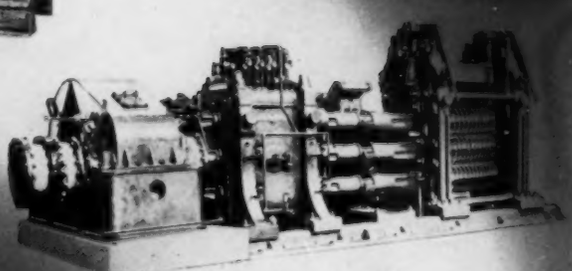




Continental

our logical source for

ROLLING MILLS AND EQUIPMENT



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FOUNDRY & MACHINE CO.

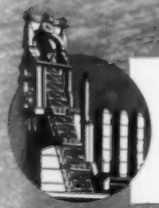
CHICAGO • PITTSBURGH

Plants at East Chicago, Ind. • Wheeling, W. Va. • Pittsburgh, Pa.

Rolling Mills and Equipment
Iron and Steel Rolls, Carbon
and Alloy Steel Castings

Giant with facile jaws

When the sturdy Brosius Auto Floor Forging Manipulator takes a billet or blank in its teeth, it improves upon every action possible with chain hoist and porter bar or cumbersome overhead equipment. More swiftly and easily it draws or charges . . . moves more quickly and independently across the forging floor . . . manipulates at hammer or press with more sensitive movements. Moreover, this remarkable modern mammoth brings to your forge shop added production, added safety, added economy — you should be using one. Write us.



BROSIUS DIVISION

Salem-Brosius, Inc., Pittsburgh 15, Pa.

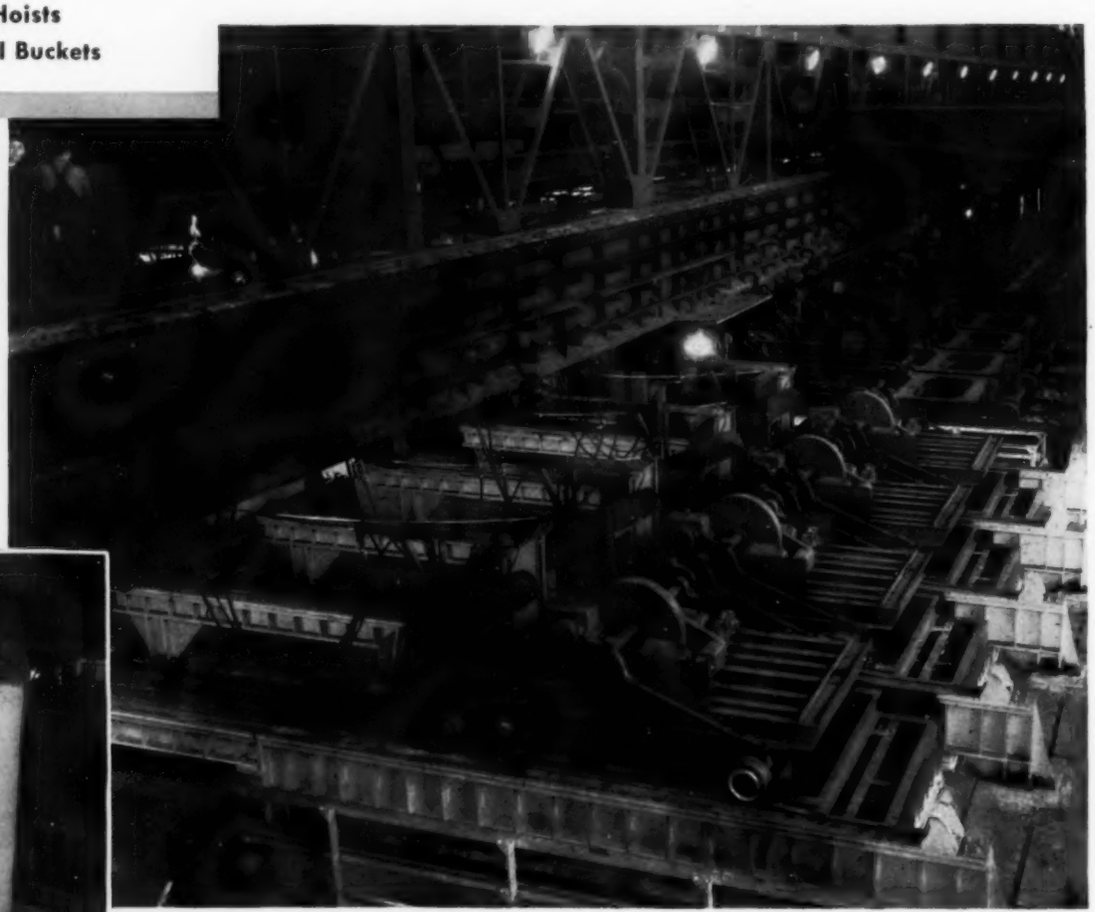
Affiliates: Salem Engineering Division,
Salem Engineering Co., Ltd., Milford nr. Derby, England; Salem Engineering (Canada) Ltd., Toronto, Canada

Wellman will build it

Special Cranes
Soaking Pit Cover Carriages
Gas Producer Plants
Ore Bridges
Charging Machines
Industrial Furnaces
Gas Reversing Valves
Coke Pushers
Mine Hoists
Skip Hoists
Clamshell Buckets

→ Wellman soaking pit cover carriages

for smooth operation...long life



In this Wellman Two-Motor Carriage, one motor raises the cover and the other motor moves the carriage.

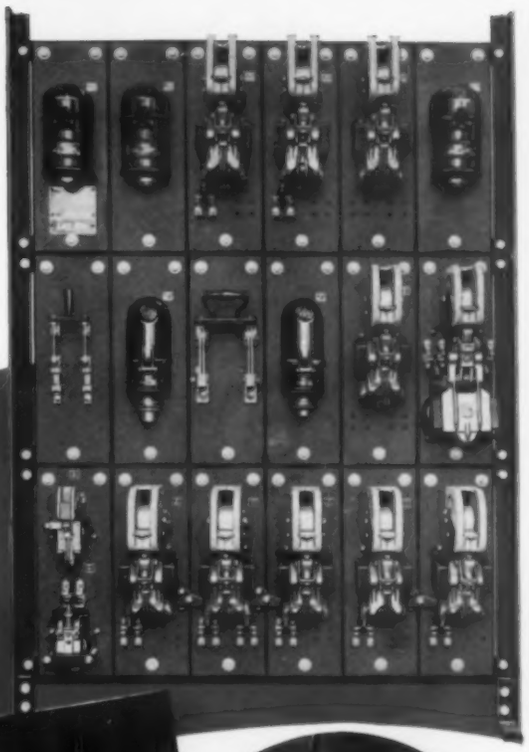
● Of rigid welded steel construction, with liberal use of anti-friction bearings, Wellman Soaking Pit Cover Carriages are recognized for their smooth, efficient performance and long trouble-free service. The installation shown above is part of a total of 46 units which are serving one large steel company. Available in various types and sizes to suit the application. Write for free bulletin No. 143.

THE WELLMAN ENGINEERING COMPANY

7031 CENTRAL AVENUE • CLEVELAND 4, OHIO

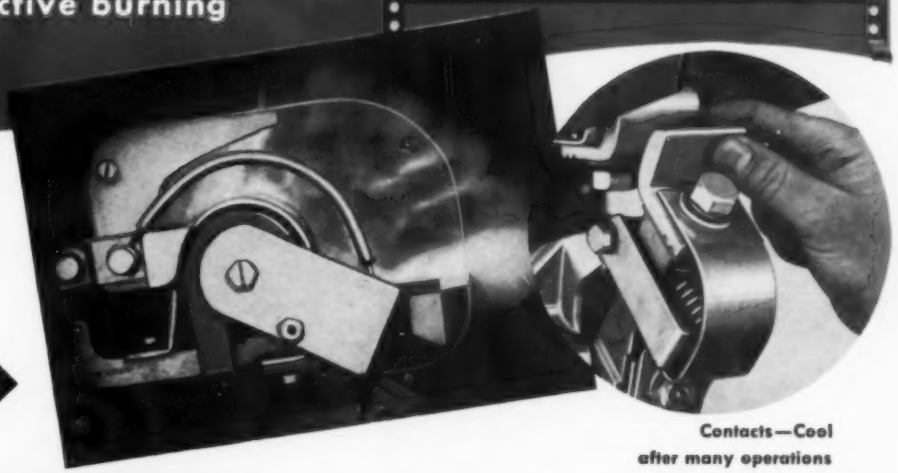
8 *Important Features of* **EC&M** *Magnetic Control*

1. Time-Current Acceleration
2. Line-Arc Contactors
3. Wright Hoist Circuit
4. Tab-Weld Resistors
5. Cam Master Switches
6. Safer Electrical Interlocks
7. Bolted, Welded Frame
8. Quick Contact Renewing



LINE-ARC Principle

- lengthens contact life
- eliminates destructive burning of arc shields



At right is shown a *LINE-ARC* Contactor specially fitted with glass arc shields to demonstrate the *LINE-ARC* principle. The glass was neither smudged nor harmed in this test.

Contacts—Cool after many operations

THE *LINE-ARC* PRINCIPLE REDUCES UPKEEP

A popular feature of EC&M LINE-ARC Contactor Control is reduced upkeep resulting from cool contact operation and centering of the arc between, but not touching, the arc shields.

LINE-ARC is an exclusive EC&M feature which proves itself wherever high output depends upon rapid and repetitive making and breaking of power circuits to the motor. When the contactor opens, the arc is transferred from the contacts quickly (in 1/500th sec.). The arc transfers to the arcing-plate and the circular guard over the blow-out coil where it is quickly extinguished.

On many cranes, ore bridges, screwdowns, side-guards and similar applications, these EC&M LINE-ARC Contactor Controllers continue to set high performance standards. Try EC&M Control for your next heavy-duty motor application.

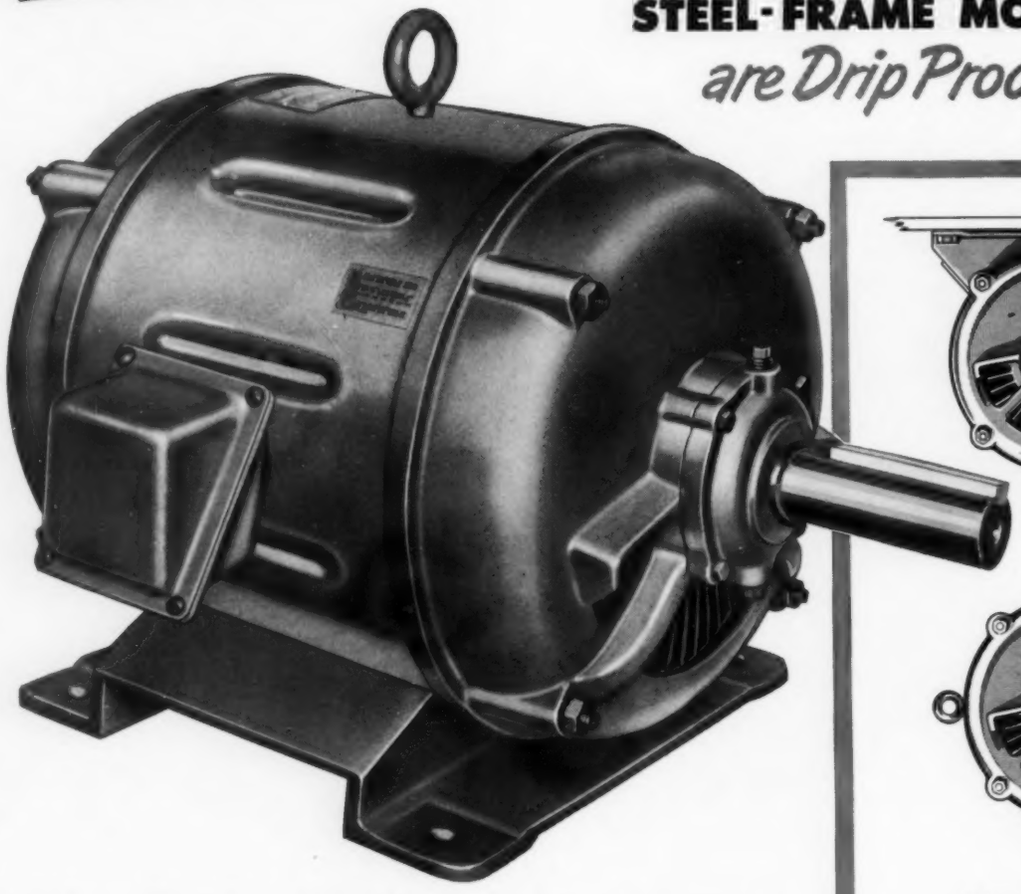
THE ELECTRIC CONTROLLER & MFG. CO.
2698 EAST 79TH STREET • CLEVELAND 4, OHIO

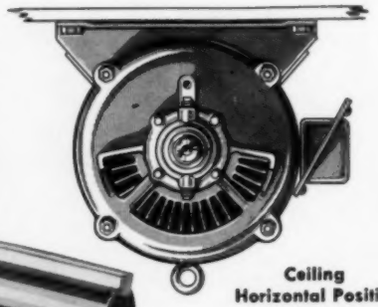
Wagner
ELECTRIC MOTORS
...the choice of leaders in industry

Ceiling Mounted-Sidewall Mounted
or in normal horizontal position

Wagner

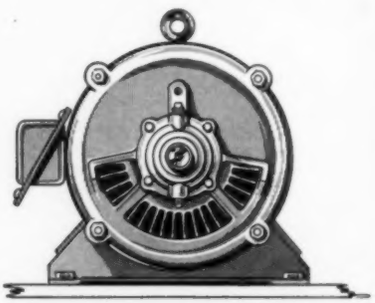
STEEL-FRAME MOTORS
are Drip Proof





Ceiling
Horizontal Position

Sidewall Horizontal Position



Normal Horizontal Position

and...they're *proved* by years of service.

Here's an open-type general purpose motor that's completely drip-proof in any horizontal position, in frames 326 and smaller, because there are no openings in the frame and the endplates can be rotated 90° or 180° for drip-proof installation on walls or ceiling.

These steel-frame, squirrel-cage motors have been *proved*—for long, useful, troublefree life by more than twenty years of hard usage in many industries. Wagner steel-frame motors are available with either sleeve or *ball bearings which may be relubricated.* The motor frames are formed of heavy rolled steel, shaped to accurately center the stator core and to provide passages for ample ventilation. An internal fan moves a large volume of cooling air through these passages to carry off heat from all parts of the motor.

Wagner Steel-Frame Motors are available in electrical types to meet most industrial requirements.

Bulletins give full information on the complete line of Wagner Motors. Thirty-one branches, located in principal cities, are ready to assist you whenever you have a motor problem. In addition, almost 650 authorized motor repair shops provide speedy, nationwide service facilities.

Wagner
Electric Corporation
1891 WE 1951

WAGNER ELECTRIC CORPORATION
6483 Plymouth Ave., St. Louis 14, Mo., U.S.A.

ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES
AUTOMOTIVE BRAKE SYSTEMS – AIR AND HYDRAULIC

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M51-18

Line-O-Power

STRAIGHT LINE DRIVES

...for quality... economy... efficiency...

Line-O-Power Double Reduction

Line-O-Power Triple Reduction

QUALITY that starts with Duti-Rated, high hardness, precision helical gears, assembled into rugged cast housings of compact, streamlined design.

ECONOMICAL to buy because the latest, most accurate high production machine tools assure rapid production with exceptional accuracy for long wear life. Economical to operate because simplified construction, minimum number of moving parts, direct splash lubrication, quality workmanship—all hold maintenance to a minimum.

EFFICIENCY—Straight line design with Duti-Rated helical gears gives efficiencies of 96%, or higher.

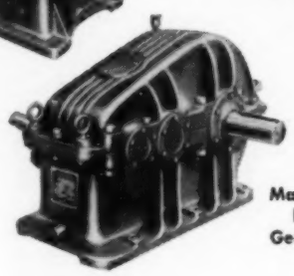
Line-O-Power Drives are available in double or triple reductions for capacities from 1 to 200 h.p. with ratios from 5 to 1 up to 238 to 1.

FOOTE BROS. GEAR AND MACHINE CORPORATION
4545 S. Western Blvd. Chicago 9, Illinois

FOOTE BROS. manufactures a complete line of enclosed gear drives to meet any requirement.

Hygrade Enclosed Worm Gear Drives

Foote Bros.-Louis Allis Gearmotors



Maxi-Power Helical Gear Drives

FOOTE BROS.

Better Power Transmission Through Better Gears

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Chicago 9, Illinois

Please send me a copy of Bulletin LPB on Foote Bros. Line-O-Power Drives.

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Company.....

Position.....

Address.....

City.....Zone.....State.....

GOULD

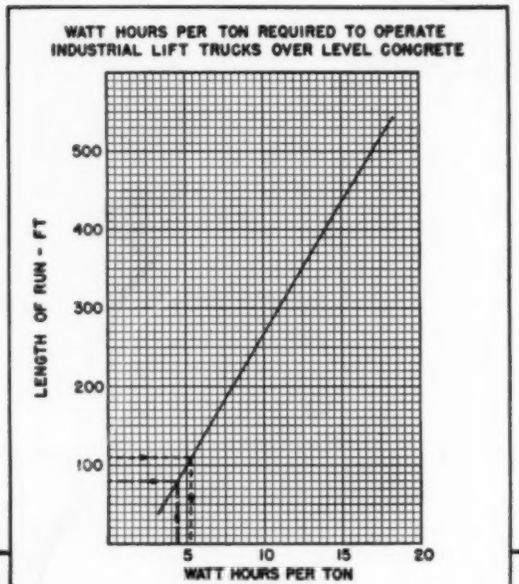
Plus-Performance Plan

...TELLS YOU HOW TO

SELECT YOUR BATTERIES TO FIT YOUR JOB!

You can increase battery performance as much as 50% through the help of the GOULD PLUS-PERFORMANCE PLAN! Here is a complete and integrated system of manuals, articles, specifications, bulletins, record cards and charts which explain and illustrate how to select, charge and handle, maintain and determine the condition of your batteries.

Designed to help you conserve and extend your essential battery power, the GOULD PLUS-PERFORMANCE PLAN is FREE to ALL battery users without obligation. A request on your letterhead will bring descriptive literature by return mail.

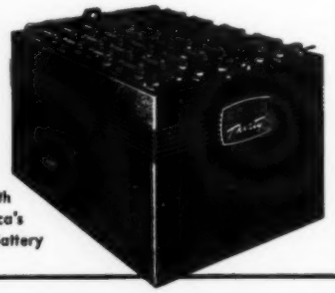


AN EXAMPLE OF PLUS-PERFORMANCE PLAN HELPFULNESS

Selection Requires Route Analysis

Battery selection should be made only after careful analysis of the route truck will travel and the load it will handle. Knowing weight of truck empty, amount of average load, average length of run and length and percent of grades encountered, simple, easy formulas enable you to calculate the battery capacity needed for 1) level run loaded; 2) going up grade; 3) return trip empty; 4) lifting; 5) tilting. The sum of these five computations gives total watt hours necessary for trip. Multiplying by trips a day gives total daily watt hours required. Dividing this total by battery voltage required gives minimum battery capacity for the job.

▲ This graph plus easily worked formulas enable you to compute required watt-hours.



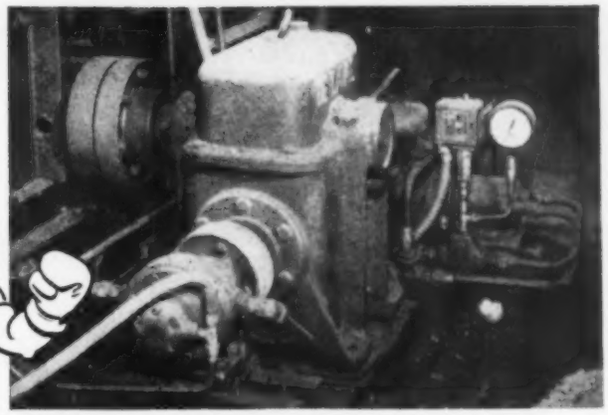
Gould "Thirty" with "Z" plates—America's Finest Industrial Truck Battery

GOULD STORAGE BATTERIES

GOULD-NATIONAL BATTERIES, INC., TRENTON 7, NEW JERSEY

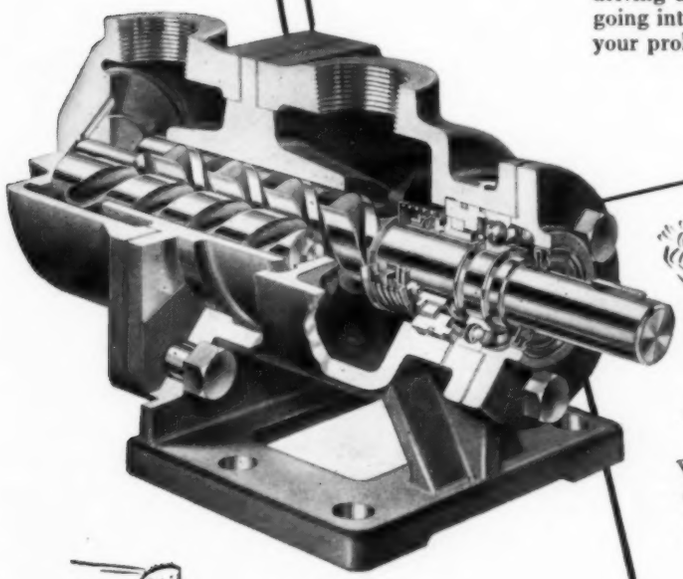
Always Use Gould-National Automobile and Truck Batteries

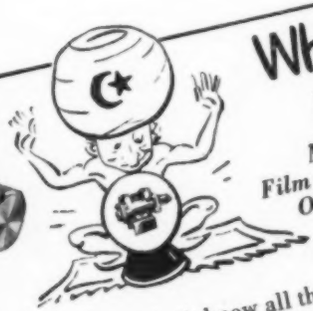
De Laval products at work!



Tough service?... You bet!

0 to 800 rpm in 8/10 Second . . . 26 Times per Minute. And this De Laval speed reducer takes it and likes it. This particular unit is driving a conveyor belt that automatically feeds and measures billets going into a shear. If you are rough on reducers in your plant, tell your problems to one of our power transmission engineers.

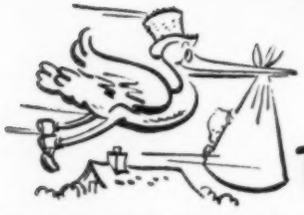




What do you want to pump?

Molasses, Glue, Lard, Soya Oil, Film Dope, Corn Syrup, Vegetable Oil, Paste, Fuel Oil, Shortening, Resin, Varnish, Linseed Oil, Viscose Rayon, Liquid Latex . . .

We frankly don't know all the other products that an IMO can pump, but if you want a better way to transfer fluids like these from one place to another, chances are an IMO can do the job for you. The IMO is a screw-type rotary pump. Its axial flow design permits liquids to be pumped close to the axis of the rotor. This means low liquid velocity through the pump and quiet pulsation-free flow. Capacities range to 1000 gpm at 500 psi and 150 gpm at 1500 psi.



There's a new idea here!

We've simplified the already simple centrifugal pump! Our new GS pump is designed so that every working part . . . every part subject to wear, is contained in one easily replaced unit rotor assembly. Through our Service and Exchange Plan new rotor assemblies are available for immediate shipment from conveniently located stocks throughout the country.

This means good service, and if maintenance ever does become necessary, all you have to do is remove the cover and end plate bolts, lift out the old rotor and drop a new one in place. *It's that easy!* Capacities to 400 gpm — heads to 230 feet.

DE LAVAL STEAM TURBINE CO., TRENTON 2, N. J.

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CENTRIFUGAL PUMPS • WORM GEAR SPEED REDUCERS • IMO OIL PUMPS

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SILENTLY, but ruthlessly *(even as you are reading this)* rust is gnawing away at machines, tanks, fences, pipes, fire escapes, metal sash, stacks —every rustable metal—inside and outdoors!

To protect your investment — to keep every possible pound of new steel for the defense program — to make all rustable metal surfaces last longer—*adopt rust control with RUST-OLEUM as an important part of your maintenance program.*

RUST-OLEUM stops rust! Its tough, pliable, rust-resisting film gives excellent protection that prevents rust losses under many difficult rust-producing conditions.

RUST-OLEUM can be applied *even* over rusted sufaces. It is not necessary to remove all the rust. Just use wire brush and sharp scraper to remove rust scale and loose rust. Economical and easy to use because no sand blasting or chemical pre-cleaning is required.

RUST-OLEUM can be obtained promptly from Industrial Distributors' stocks in principal cities of the United States and Canada. Anticipate your needs and order now! For complete catalog see *Sweet's*, which also lists your nearest source of supply, or write on your company's letterhead for full information.

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"Rigid Economy Men!"

RUST-OLEUM
Stops Rust

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Golden Anniversary

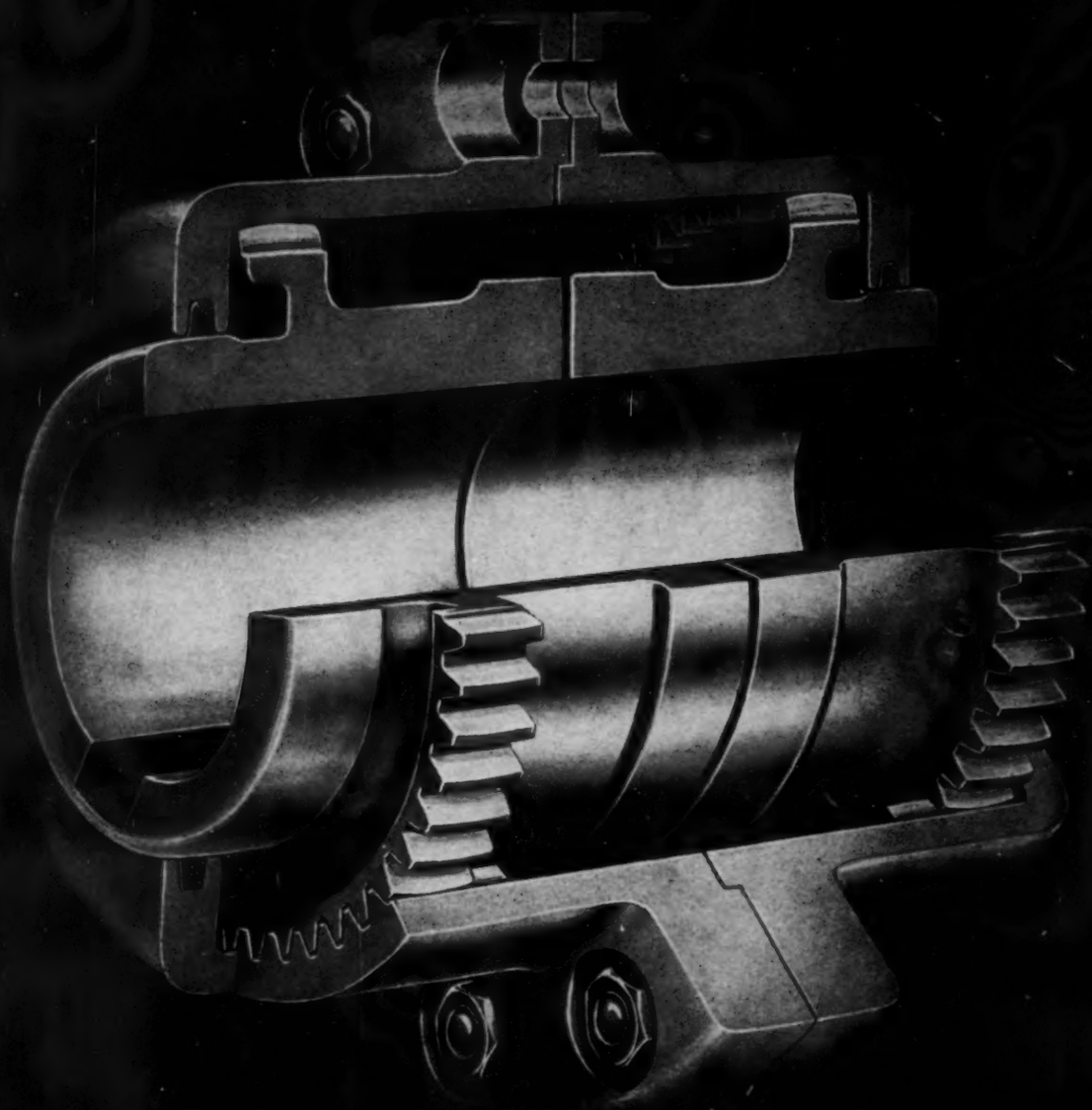
1901 — 1951

UNITED

ENGINEERING AND FOUNDRY COMPANY

PITTSBURGH, PENNSYLVANIA

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

DURABLE • DEPENDABLE

PYLE-NATIONAL

Heavy Duty Plugs and Receptacles

1, 2, 3, 4, 6, 8 pole interchangeable contact units

FOR PORTABLE ELECTRICAL EQUIPMENT

Pyle-National plugs and receptacles are built to withstand the most severe operating conditions, as proven by years of remarkably dependable service in a wide variety of industrial applications. The many substantial construction features of this extensive line of plugs and receptacles and the high quality of materials and workmanship insure safe operation, uninterrupted service and long life.

QuelArc • *Circuit Breaking Series* **Unique partitioned insulation provides long insulated paths through air and across surfaces for exceptional protection in these current rupturing devices. Galvanized cast metal housings, bakelite insulation and individually renewable contacts insure long service life. Ratings 20, 30, 60, 100 and 200 amperes, 250 volts DC, 600 volts AC—2, 3, and 4 pole—grounded through shell or extra pole. Threaded cap, plain and hinged spring door housing styles are available.**

Triploc *and Multiple-Circuit Series*

A line of exceptional versatility, unequalled in the heavy duty field, with a virtually unlimited number of assembly combinations for varied applications. Offers a selection of 1, 2, 3, 4, 6 and 8 pole contact units which are interchangeable and reversible in any single set of housings. Many types of single housings available of pressed steel with automatic lock and of cast metal threaded for watertight gasket seal. Multi-Circuit housings—2, 3 and 4 gang—available for combinations up to 32 poles. Ratings 15 and 20 amperes, 250 volts DC, 460 volts AC—circuit breaking. Pressed steel fusible and fuseless plugs measure 1 11/16″ outside diameter.

Midget Triploc *Series* **Same construction features as Triploc except for much smaller outside diameter of plug shell—only 1¼″. Interchangeable and reversible contact units—2, 3 and 4 pole—are of the flat blade type. Rated 10 amperes, 250 volts; 15 amperes, 125 volts.**

2-Gang Receptacle

Fusible Plug

Fuseless Plug

General Purpose *Series* **Available with cast metal housings in many types for circuit breaking and disconnect service. 30 amperes, 125 volts DC, 250 volt AC—1, 2, 3, 4, 5 and 6 pole. 60 amperes, 250 and 600 volts—3, 4 and 5 pole. 100 ampere, 250 and 600 volts—2, 3 and 4 pole. Also many special types, fusible and fuseless, for varied applications.**

THE PYLE-NATIONAL COMPANY

1383 NORTH KOSTNER AVENUE, CHICAGO 51, ILLINOIS

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CONDUIT FITTINGS • FLOODLIGHTS • TURBO-GENERATORS • LOCOMOTIVE HEADLIGHTS • MULTI-VENT AIR DISTRIBUTION

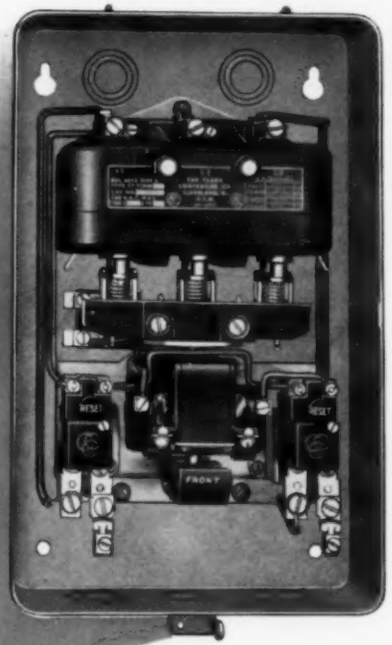
It's All New CLARK "CY"

the AC MOTOR STARTER

that gives you

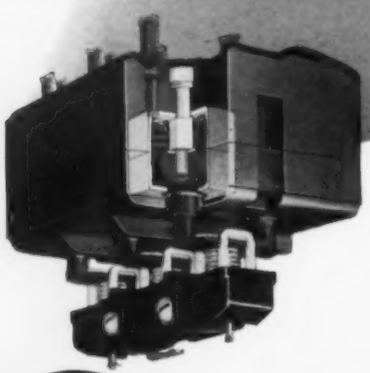
MILL TYPE HEAVY DUTY CONSTRUCTION *and* DESIGN

at NO PREMIUM above regular starter prices!



Here for the first time is a line of AC Magnetic Starters that provide the extra protection and dependable operation usually associated with rugged Mill-type equipment—at NO EXTRA COST! The ingenious design of the arc chamber and an entirely new principle of arc interruption plus other refinements, give you these advantages:

- **Forced rotation of arc minimizes burning and pitting of contacts.**
- **No filing, dressing or cleaning of contacts.**
- **No carbonization to shorten contact life or cause high operating temperatures.**
- **No accumulation of ionized gases between wiring terminals to cause phase-to-phase failures.**
- **No tools needed to inspect contacts.**



Featuring **MULTI-TURN MAGNETIC BLOWOUTS** *and Twin-Break Contacts*

The advantages of strong blow-out coils and twin-break contacts are combined in the **CLARK "CY"** to give you new standards in starter performance. This is a FIRST in electrical control history.

Let a **CLARK** *application engineer show you what this new starter means to you in increased production and lower maintenance.*

ENGINEERED ELECTRICAL CONTROL

THE CLARK CONTROLLER CO.

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ALLIANCE

improved

SOAKING PIT CRANE

with MULTI-PURPOSE tongs

● Here's a rugged, lighter weight Soaking Pit Crane that handles any width slab or ingot. It'll make bottom . . . afford the same visibility as the high rack type Soaking Pit Crane, yet takes up no more head room than a low type Soaking Pit Crane.

Special features include: telescopic ram, all operating mechanism located on deck of trolley, operator's cage on deck of trolley provides best visibility and greatest distance from all sources of heat.

Multi-Purpose Tongs provide gripping range of 6" minimum to 66" maximum opening. Consequently, a much greater range of ingot and slab sizes can be readily handled.

The Multiple Range Tongs can be installed on any model or make of Soaking Pit Crane by Alliance Engineers who will be happy to discuss your specific requirements or give you general information of interest to your industry.

- MAXIMUM RANGE CAPABILITIES
- CRANE REQUIRES MINIMUM SPACE
- AFFORDS MAXIMUM VISIBILITY
- ALL MECHANISM EASILY ACCESSIBLE
- KEEPS OPERATOR AWAY FROM HEAT

THE ALLIANCE MACHINE COMPANY

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• • • • Pouring production! Production of all the things we need in our daily lives... and the things we require to preserve our freedom. The contribution of steel to our economy and our security is unmatched by any other industry.

Only with the help of the refractory industry could steel have achieved its fabulous progress. Only with the development of better and more diversified refractories and adequate production could steel deliver today's tonnage.

In the rapid growth of steel, General

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GENERAL REFRACTORIES

GENERAL REFRACTORIES COMPANY
PHILADELPHIA

Refractories has played an important part. Wherever you go in the steel plant you'll find General products. Fireclay brick... silica brick... basic brick... including the famous STEELKLAD. You'll find, too, plastics and castables and bulk products of every description.

But General offers more than variety. It offers modern research facilities and production methods. It offers 43 mines, 29 plants, 18 sales offices and 200 distributing agencies, here and abroad. General really offers you a complete refractories service!

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better measurement and control of

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Wherever highest accuracy and complete reliability in flow measurement and control are vital to successful processing, it is significant that Foxboro Instrumentation is preferred. Whether your problem involves gas, steam, or liquids . . . in pipes, ducts, or open channels . . . the premium quality and complete diversity of Foxboro Instruments, backed by unequaled application experience, assure you an extra measure of satisfaction.

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THE FOXBORO COMPANY • FOXBORO, MASSACHUSETTS, U.S.A.

ROLLING MILL DRIVE
with the accent on *Reliability*

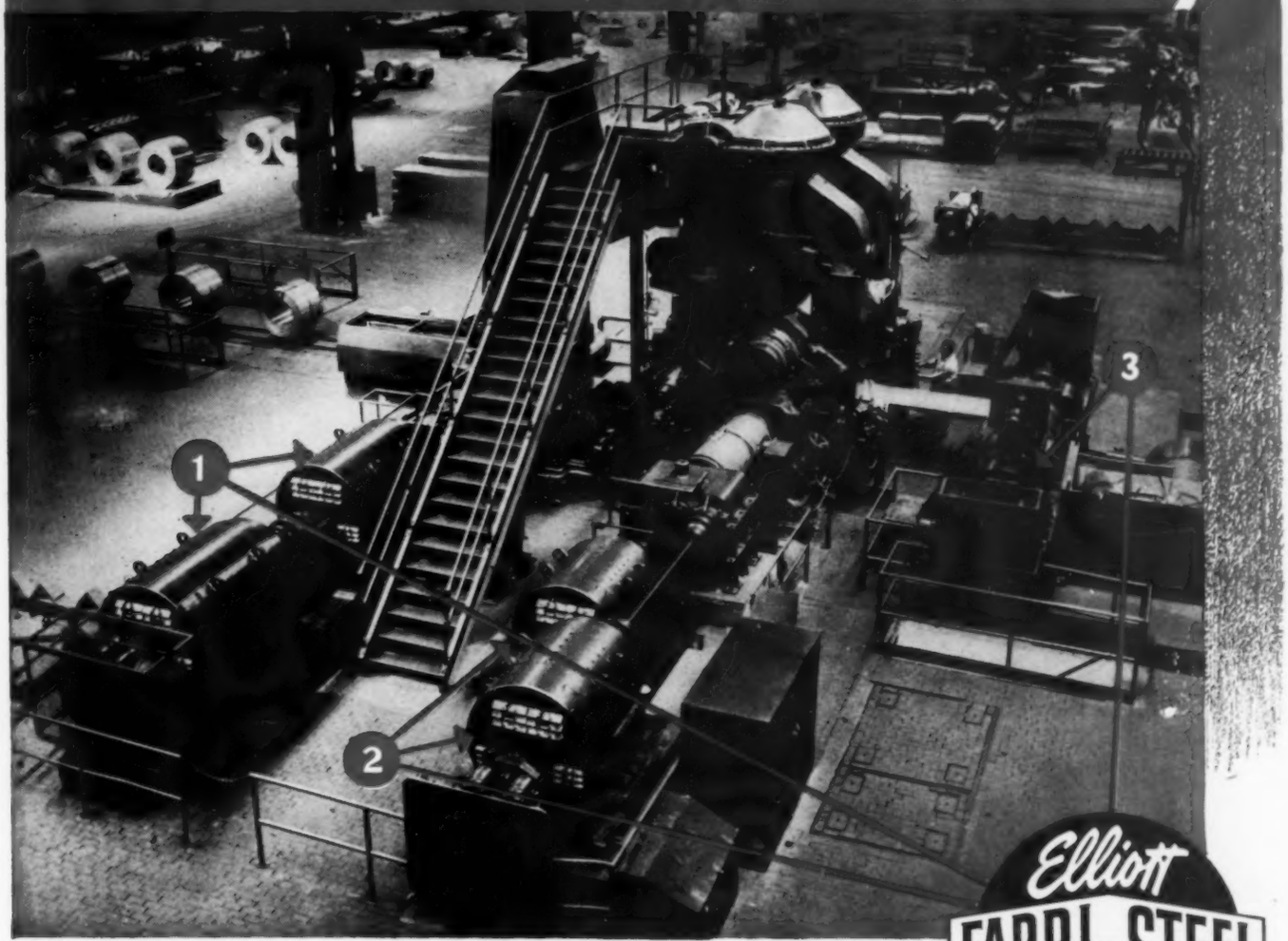


Photo courtesy of United States Steel Company — E. W. Bliss Company mill shown.

The six Elliott motors and generators in this rolling mill installation illustrate the successful combination of *progressive design,* extreme care in *materials selection,* and highest degree of *precision* in craftsmanship. The end result is the *reliability* essential to rolling mill operation—a quality for which Elliott motors and generators are noted throughout all industry. For details on equipment illustrated, write us.

Elliott
FABRI-STEEL
MOTORS AND GENERATORS

1 Two tandem-coupled 500-hp, 250/965-rpm recoiler motors.

2 Two 600-hp, 450/1000-rpm main roll twin-drive motors.

3 Two 150-kw, 300/1200-rpm drag generators.

The 2100-kw Elliott motor-generator set furnishing variable voltage power to these machines, is installed below the mill floor.

MR-9

ELLIOTT COMPANY

DEPARTMENT 15
Ridgway Division • Ridgway, Pa.
Plants at: JEANNETTE, PA. • RIDGWAY, PA.
AMPERE, N. J. • SPRINGFIELD, O. • NEWARK, N. J.
District Offices in Principal Cities

1901 1951

blast furnace skip-hoist drive

cuts skip-cycle time, simplifies speed control!

Dual motor-and-generator drive—G-E engineered and G-E equipped—holds constant speed regardless of load, provides faster acceleration and deceleration, lengthens machine and rope life!

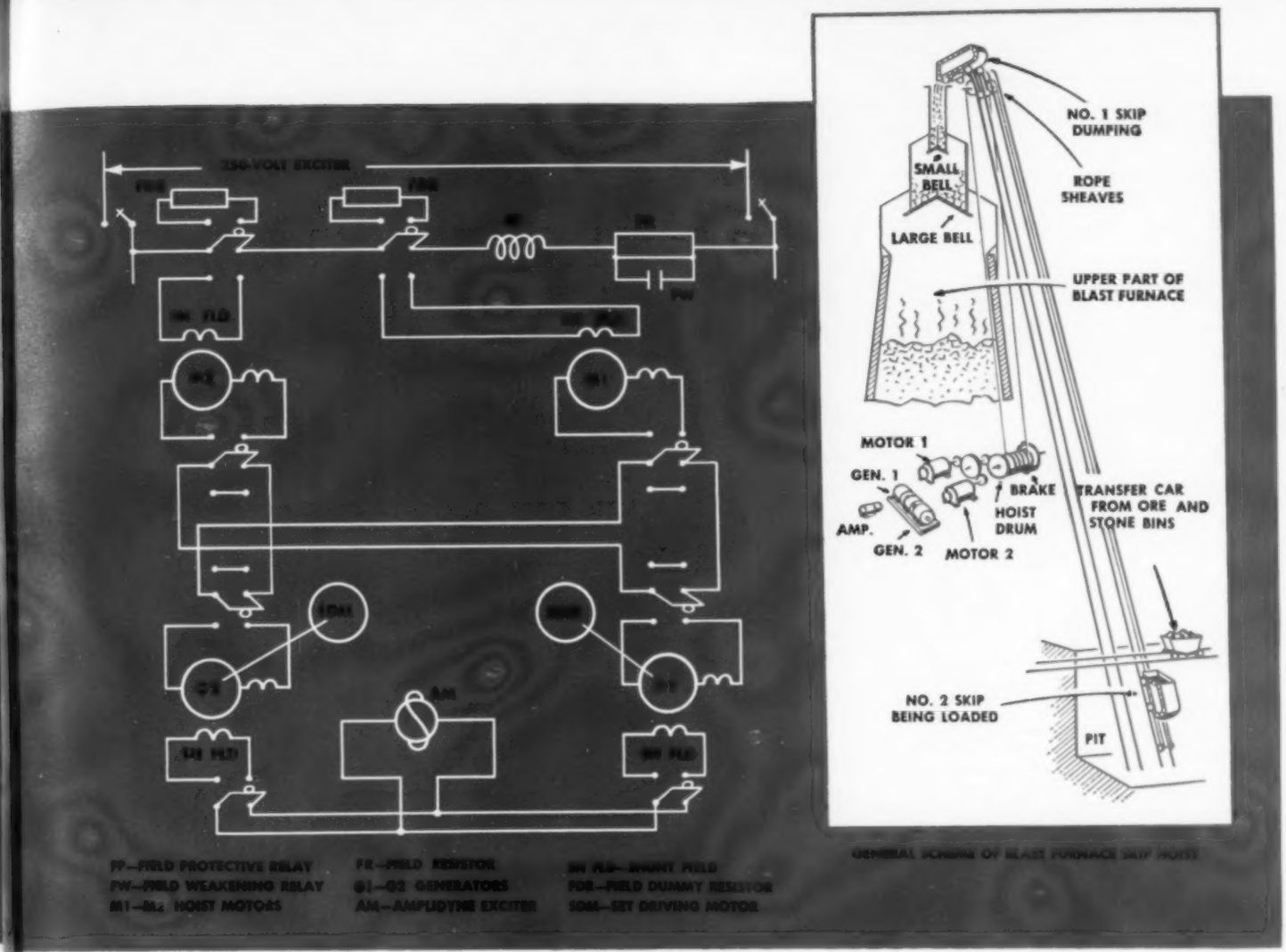
Utilizing the quick response and versatility of the G-E amplidyne, this skip-hoist drive employs two shunt-wound, 150-hp G-E mill motors designed for "field-forcing" to drive the hoist drum. With the motors connected to two generators, excited by the amplidyne, the drive provides these outstanding advantages:

- **Continuity of operation in an emergency.** Hoist may be operated with either motor or either generator, or with one set shut down, without too great a reduction in hoist output.
- **Constant hoist operating speed, regardless of load carried.**
- **Equal division of load between machines.**
- **High starting torque per ampere of armature current.**
- **Simplified control.** Numerous armature and field contactors are avoided.
- **Faster acceleration and deceleration of the skip.** Accelerating current is maintained substantially constant. This reduces over-all skip-cycle time and increases hoise output.
- **A wide range of operating speeds.** This permits close co-ordination of skip-hoist action with furnace needs.
- **Reduced mechanical stress on machinery and haulage ropes.** Longer equipment life is obtained because of the amplidyne's current and torque limit control.

This engineered drive is one more illustration of the advantages of calling us in on your drive problems. Let a G-E specialist discuss complete blast furnace electrification with your technical men. Today, a well-engineered and co-ordinated electrical system is a necessity for continuity of your blast furnace operation. *General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

659-58



HERE'S THE ELECTRICAL STORY BEHIND THIS NEW G-E DRIVE:

As shown schematically above, the skip hoist is driven by two shunt-wound mill type motors (M1 and M2), with their armatures electrically connected in series with generator armatures (G1 and G2). Full speed and slow-down speed of the hoist are controlled by automatically adjusting the armature voltage of the generators. The hoist is started from push-button stations on the master control unit in the stock house, or from a master switch in the skip house. When the hoist starts, the shunt fields of the motors are "forced," to obtain maximum torque per ampere of armature current. High starting torque is necessary because of the unbalanced rope pull existing when the loaded skip is in the pit.

The pre-selected operating speed of the hoist is controlled by a control field in the amplidyne exciter (AM1). Another control field in the amplidyne exciter limits the armature current of the generator. When the skip bucket approaches the dumping knuckle, it is automatically slowed down by a limit switch to a preset speed. This speed is substantially the same whether the load is heavy iron ore or light coke. This limit switch also controls the stopping of the hoist.

Transfer knife switches are provided so that either motor and generator may be disconnected quickly and the hoist operated with normal loads at reduced speed.

another example of
GENERAL ELECTRIC
drive engineering at work!

You can pick out

THE MAIN REASON WHY THIS FARREL® DRIVE IS SO EFFICIENT

The high efficiency and quiet operation of a Farrel combination mill drive and pinion stand are due to a large extent to precision generation of gears and pinions by the famous Farrel-Sykes process. This method of generation assures extreme accuracy of tooth spacing, contour and helix angle, which pays off in smooth, uniform power flow.

To keep power-transmission efficiency "young" through long years of service, the drive is equipped with a unit-type pressure lubricating system with separate motor-driven pump. This provides a continuous spray of oil at the mesh line of all gears and pinions and force-feed lubrication to all antifriction bearings.

Designed to suit individual requirements, Farrel rolling mill drives and pinion stands — separate or combination units — are available in any capacity. Farrel engineers will be glad to supply full information for any specific application.

FARREL-BIRMINGHAM COMPANY, INC., ANSONIA, CONN.

Plants: Ansonia and Derby, Conn., Buffalo, N. Y.
Sales Offices: Ansonia, Buffalo, New York, Akron, Pittsburgh, Chicago, Los Angeles, Houston

— FARREL ROLLING MILL MACHINERY —

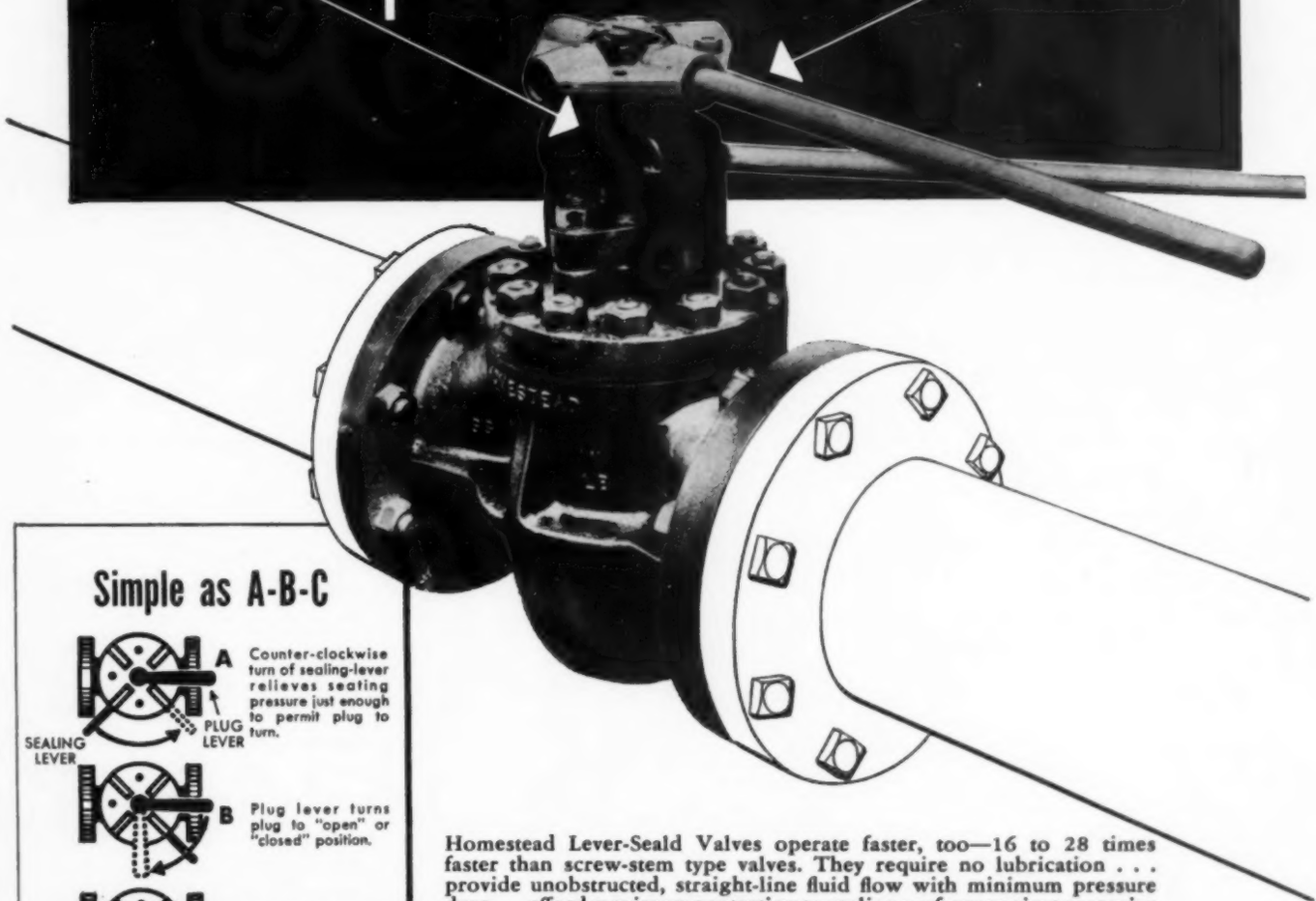
Rolls • Rolling Mills • Mill Tables and Manipulating Equipment • Universal Mill Spindles • Rod Coilers • Gears • Mill Pinions • Pinion Stands • Gear Drives of Any Capacity • Flexible Couplings • Roll Grinding Machines • Roll Calipers • Lead Presses for Pipe or Rod.

FB-688

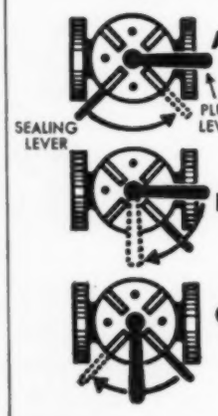
- at all times
- under all conditions
- throughout its long lifetime of service

This Homestead Valve will always work

it's **stickproof** because it's **lever-seald**



Simple as A-B-C



A Counter-clockwise turn of sealing-lever relieves seating pressure just enough to permit plug to turn.

B Plug lever turns plug to "open" or "closed" position.

C Clockwise turn of sealing-lever restores full seating pressure.

Homestead Lever-Seald Valves operate faster, too—16 to 28 times faster than screw-stem type valves. They require no lubrication . . . provide unobstructed, straight-line fluid flow with minimum pressure drop . . . afford maximum protection to sealing surfaces against corrosive and erosive line fluids. And because only a quarter-turn is needed for full opening or closing, they are ideal for installation in restricted areas where operation of other types of valves might be difficult.

Next time you have damaged or sticking valves, replace them with Homestead Lever-Seald Plug Valves. Once you use them you'll never be satisfied with ordinary valves.

For complete information write for Valve Reference Book No. 39-3.

HOMESTEAD LEVER-SEALD PLUG VALVES

HOMESTEAD VALVE MANUFACTURING COMPANY

Serving since 1892

P.O. BOX 21 CORAOPOLIS, PA.

today piping repairs cost more!

Crane No. 465½
Iron Body Gate Valve

You make fewer of them

by using Dependable Quality

CRANE VALVES

...That's why more Crane Valves are used than any other make

No bonnet joint trouble with this valve

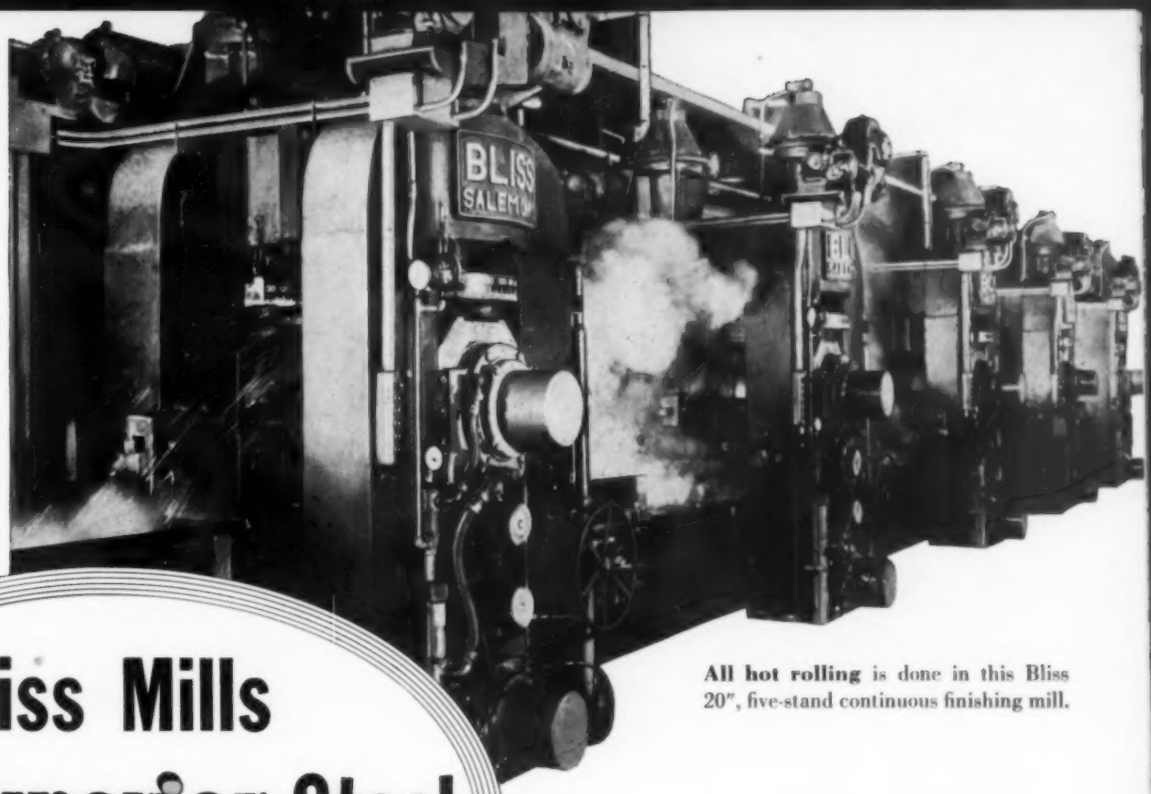
A typical example of low-cost maintenance—Crane No. 465½ 125-Pound Iron Body Gates. Rarely does the bonnet joint need attention. Flange construction includes reinforcement to prevent distortion and utilizes more bolts, more closely spaced, than is usual in valves of this class. Crane precision-guided seating reduces seat and disc wear. Packing has long life because these valves have a deep stuffing box filled with high grade asbestos ring packing. A ball-type gland helps to equalize the packing load.

Better performance features like these make Crane the better buy in valves of every type. They assure low maintenance cost—low ultimate valve cost—for every piping service.

CRANE CO.

General Offices:
836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



All hot rolling is done in this Bliss 20", five-stand continuous finishing mill.

Bliss Mills pace Superior Steel expansion

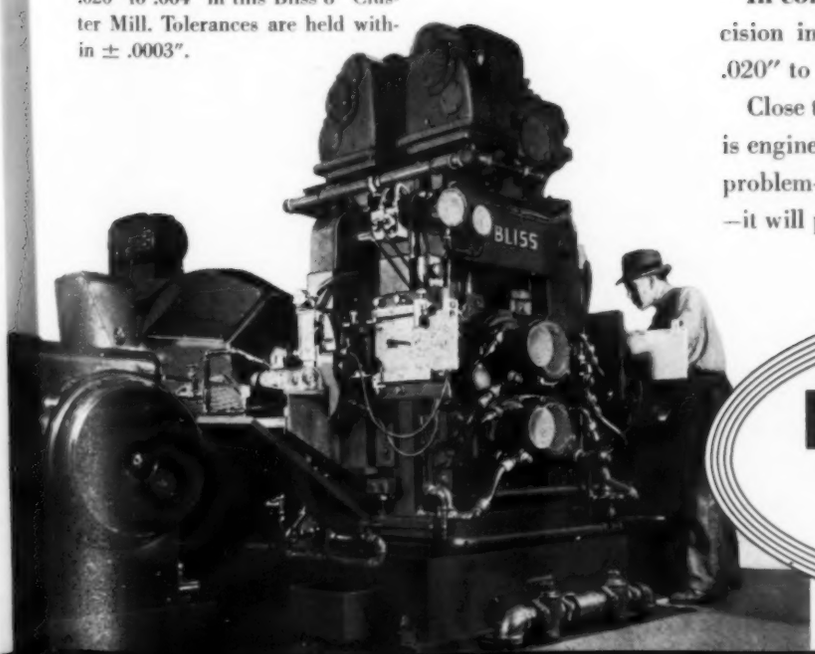
Now, almost all mills and auxiliary equipment used by Superior Steel Corporation to produce "specialty" steels—clad, stainless, special-alloy and high-carbon spring steel—are Bliss-built.

All hot rolling is done on a new Bliss 20", five-stand continuous finishing mill, which replaced two older mills. Since much of the thin stainless steel is slit into very narrow strips, extreme accuracy and flatness are vital. The Bliss mill not only produces more than the former mills together, but turns out a better product, according to Superior engineers.

In cold rolling, a new Bliss Cluster Mill gives optimum precision in light-gauge narrow strip. This mill rolls metal from .020" to .004" and holds tolerances within ± .0003".

Close tolerance, high-speed rolling of any metal, in any gauge, is engineered into Bliss rolling mills. Whatever your equipment problem—breakdown, finishing or material-handling accessories—it will pay you to put your problem up to Bliss.

Light-gauge metal is rolled from .020" to .004" in this Bliss 8" Cluster Mill. Tolerances are held within ± .0003".



E. W. Bliss Co.

General Office: Canton, Ohio

Rolling Mill Division

Salem, Ohio

Get in ALL Your Scrap---Profitably

with OXWELD Equipment

Trade-Mark

Here's the OXWELD *C-60 Cutting Blowpipe in action . . . slicing up a steel button 6 ft. thick with ease!*

Oxygen cutting rapidly converts steel sections of every size, shape, and type into good, usable scrap. Any thickness is easily reduced to charging-box size with OXWELD equipment. And no job is too tough. Whatever your scrap-cutting problem, there's an OXWELD blowpipe to solve it efficiently and economically.

For the extra-heavy jobs, the OXWELD C-60 Cutting Blowpipe with powder-cutting attachment is the answer. Especially engineered for cutting spills and ladle skulls, this combination easily makes continuous cuts through 6 ft. of dirty, slag-incrusted steel.

Other highly adaptable OXWELD blowpipes speed up medium scrapping operations. Mounted on portable, lightweight machines, they work on a production basis, cutting ingots, castings, and risers into sizes convenient for charging into the furnace.

On the lighter jobs, sturdy OXWELD hand-cutting blowpipes ready steel scrap up to 12 in. thick for the charging box. With 57 different nozzles to choose from, you get maximum efficiency at lowest overall cost.

LINDE has accumulated a vast amount of practical experience in helping to solve many unusual scrapping problems. If you have a scrap-cutting problem, ask our nearest office for help. We have the know-how, the "show-how," and everything you need to do the job profitably.

The term "Oxweld" is a registered trade-mark.

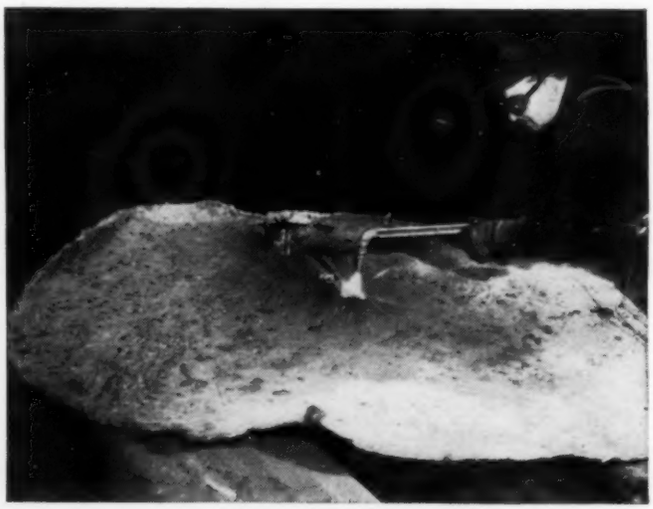
LINDE AIR PRODUCTS COMPANY

A Division of Union Carbide and Carbon Corporation

30 E. 42nd St., New York 17, N.Y. UCC Offices in Other Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

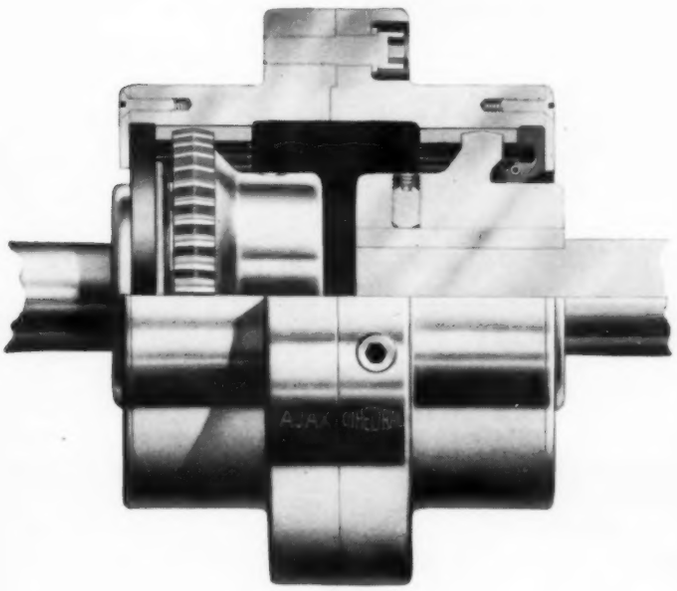
A lightweight OXWELD *portable machine speeds this scrap-cutting operation. Setup is semi-automatic and portable . . . can be easily moved from one job to another.*

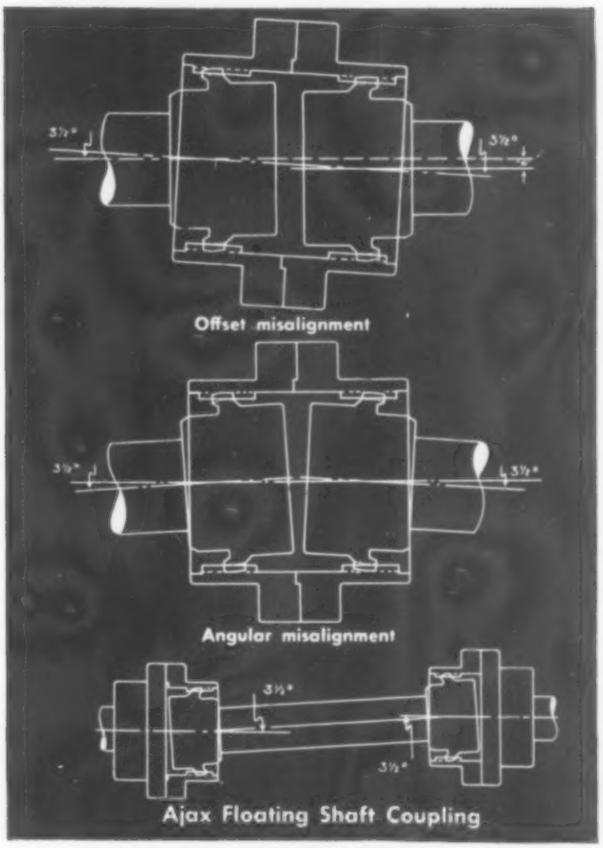


Spills, salamanders, and other mill scrap can be cut quickly and efficiently with an OXWELD *hand-cutting blowpipe . . . and with minimum gas consumption.*

EVERY MAN WHO HAS MISALIGNMENT TROUBLES WELCOMES THIS SENSATIONAL NEW

AJAX DIHEDRAL COUPLING





● Ajax Dihedral Couplings eliminate misalignment problems. They simplify machine design and cut installation time.

New and exclusive Ajax tooth shape provides for maximum misalignment up to 7° with tooth clearance (backlash) kept to oil film requirements. Long life is assured because more tooth contact is maintained under operating conditions than with any other shaped tooth. 30 degree involute splines provide strong basic tooth form.

Positive oil seals keep lubrication in and dirt out.

If you use couplings, *write for new Bulletin 50.*

THE GEAR TYPE COUPLING THAT HANDLES MISALIGNMENT HERETOFORE CONSIDERED EXCESSIVE

AJAX FLEXIBLE COUPLING CO. INC.

WESTFIELD, NEW YORK

CONTINUOUS STRIP ANNEALING in DREVER VERTICAL FURNACES

Saves Time • Reduces Cost

Outstanding PRODUCT

A Uniformly annealed strip from edge to edge and end to end of coil.

B Uniform Physicals throughout the coil

C Clean, Lustrous Surface that electro-tins uniformly

D Stickers and "Dog Ears" eliminated

E Users of Continuous Annealed Strip report longer die and shear life

Drever Company has pioneered this striking improvement in Continuous Annealing Furnaces for Tin Plate Strip, Silicon Strip, Blue Plate and other strip products. We predict all major steel mills will anneal by this method. Why don't *you* do it now?

Equipment can be specified for output up to 30 tons per hour of 30″ wide x .010″ thick low carbon steel. Several sizes are available, in any width.

Furnace illustrated produces Tin Plate and Blue Plate. The shift-over from the Bright Surface required for Tin Plate to the uniformly applied, accurately controlled tight oxide coating required for blue plate is rapidly and easily made.

Installations backed by staff of Engineers and Metallurgists of sixteen years experience in Continuous Annealing of Low Carbon Strip.

Outstanding DESIGN

1 Speeds up to 1000 feet per minute

2 Controlled Strip Tension, excellent tracking

3 Controlled Heating and Soaking Time

4 Regulated Cooling Rate

5 Predictable Strip Temper

6 Cleaning in same line

7 Low Maintenance

8 Reduction in Floor Space

9 Reduction in Coil Inventory

10 Overall Saving in Annealing and Cleaning Costs

DREVER CO.
730 E. VENANGO STREET
PHILADELPHIA 34, PENNA.

M-H Red Wabbler Rolls always have that extra service capacity to cope with the heavy demands you're now making on your plate mills.

PLATE

rides the rails, the high seas, the inland waterways

Strong and tough, with the fine grain structure required for intermediate and finishing stands, Mack-Hemp NIRONITE Rolls are on the job day after day in the mills which roll most of the nation's annual production of 5,759,065 net tons of plate. Of this tonnage, the public transportation industry uses about 25% annually.

Since the first alloy rolls were pioneered by Mack-Hemp, improvements in *striped red wabbler rolls* have paralleled the developments in mills and rolling techniques.

Where there's a productioneering job to be done in the rolling of metal you'll find a Mack-Hemp Roll equal to the task. The continuing program of research in metallurgy and manufacturing practices at Mackintosh-Hemphill Company make it increasingly important for you to keep an eye on what's new at Mack-Hemp.

MACKINTOSH-HEMPHILL
COMPANY
Makers of the Rolls with the Striped Red Wabblers
PITTSBURGH and MIDLAND, PA.

Mackintosh-Hemphill Products Include: rolls . . . steel and special alloy castings . . . completely integrated strip mills . . . heavy duty engine lathes . . . Mackintosh-Hemphill rotary straighteners . . . improved Johnston patented corrugated cinder pots and slag-handling equipment . . . shape straighteners . . . end-thrust bearings . . . shears . . . levellers

P-G Limit Switch *Resistors* . . . . . .

for use with . . .

CRANE HOIST SAFETY LIMIT STOPS!

P-G Limit Switch Resistors are available for use with any crane hoist safety limit switch operating on direct current from 5 HP to 200 HP.

Design of the P-G Resistance Grid is ideal for safety limit stop operation because it produces a resistor element of sufficient mechanical strength to withstand the brief but heavy overloads peculiar to this service.

Constructed from the same basic parts used for P-G Standard Unit Resistors, long trouble-free service is assured without worry over vibration, moisture or corrosive fumes.

Standard enclosures as illustrated give ample protection from ordinary outside mechanical damage with no sacrifice of ventilation so necessary for dissipation of heat.

Try a P-G Limit Switch Resistor on your next application, particularly, if service conditions are severe.

Detailed information in BULLETIN No. 500

Copy on request

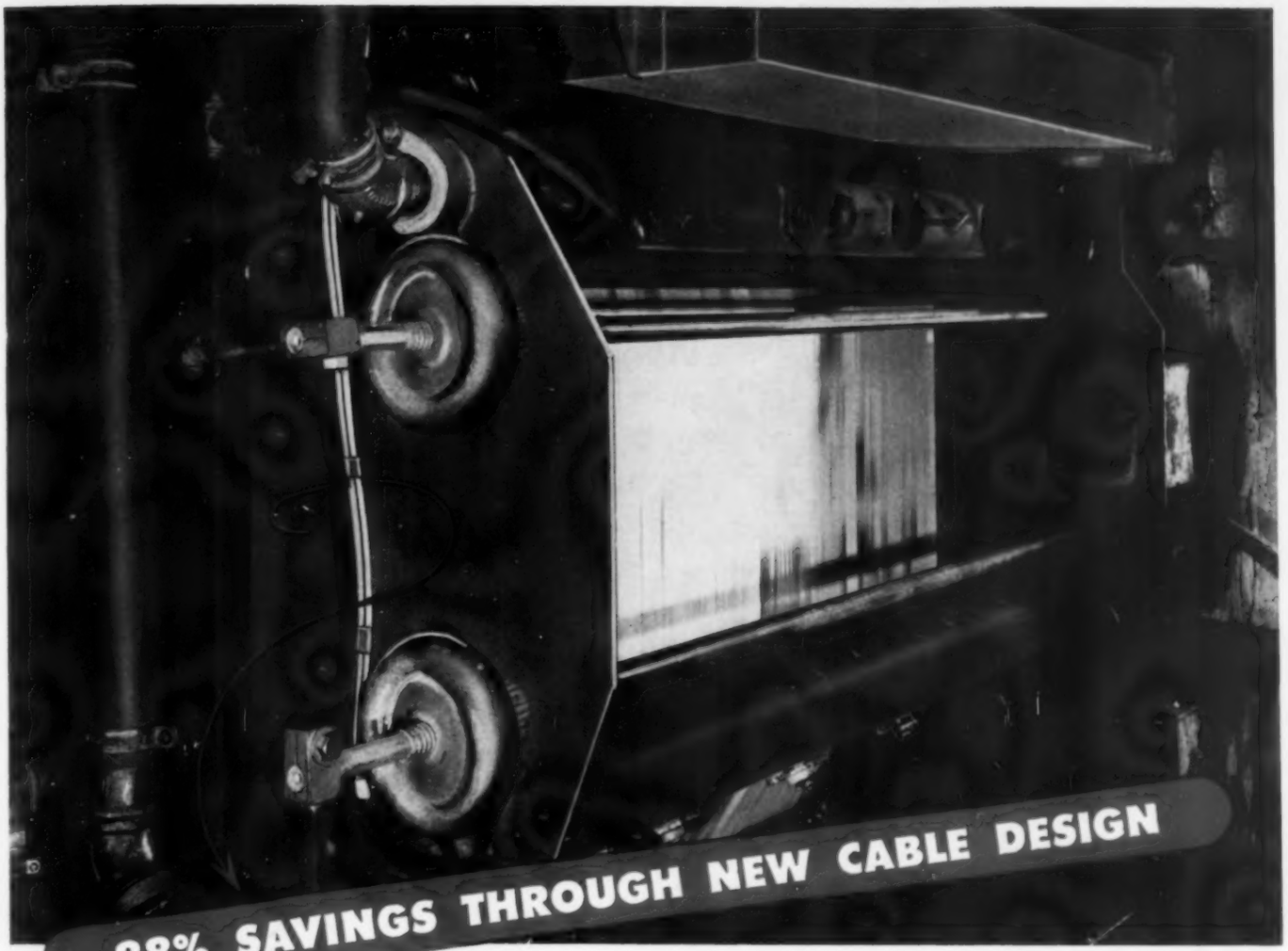
P-G

The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI 2, OHIO



How Okonite-engineered cables save money for the McCall Corporation

Engineers of the McCall Corporation, Dayton, Ohio, sought a means of reducing their insulated cable replacements on six printing presses. The ordinary cables used for supplying the gas ignition apparatus failed quickly because of temperatures ranging from 350 to 450°F. Monthly replacements of the standard rubber-insulated automotive ignition cable previously used gave rise to the following costs:

BEFORE

Cost of cable per year	**$650.00**
Labor in replacement	**900.00**
Yearly cost: materials and labor	**$1550.00**

In 1948, at the suggestion of an Okonite engineer, McCall installed Okonite's heat-resistant Okotherm cable. Since then, no replacements have been made under conditions of normal usage. Although the Okotherm cable was several times as expensive, experience has already shown that annual costs have been reduced to a mere fraction of the previous cost, as follows:

NOW

Cost of cable per year	**$142.00**
Labor on installation	**37.50**
Total yearly cost using Okotherm	**$179.50**

...a saving of 88.5%

● ● ●

Stories like this are not unusual in the file of actual case histories at Okonite. For the broad research and design and manufacturing skills which have developed such long-lived, trouble-free cables for normal use, have also developed many types for highly specialized applications.

These facilities are available to *you*, to help solve any difficult cable problems arising in *your* operation. Don't hesitate to call in your nearest Okonite representative, or write The Okonite Company, Passaic, N. J.

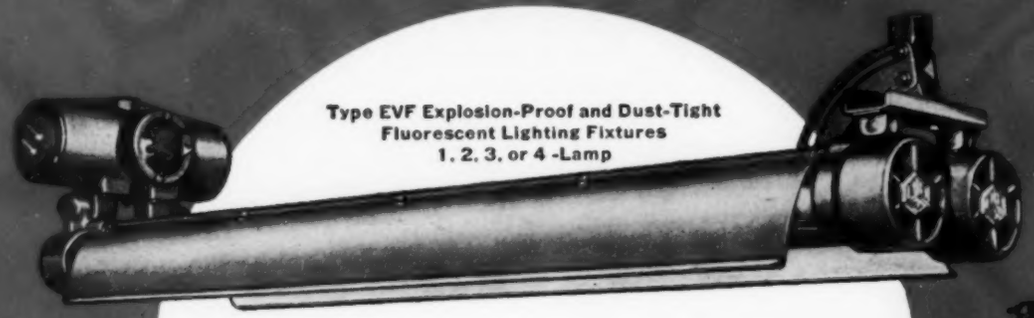
OKONITE OKONITE SINCE 1878

THE BEST CABLE IS YOUR BEST POLICY

insulated wires and cables

9188

CROUSE-HINDS High Efficiency LIGHTING EQUIPMENT...



Type EVF Explosion-Proof and Dust-Tight Fluorescent Lighting Fixtures
1, 2, 3, or 4 -Lamp

. . . for Hazardous Locations

Crouse-Hinds explosion-proof lighting fixtures exceed the requirements for service in highly explosive atmospheres. They are designed to operate at a temperature below the ignition temperature of the gas-air or vapor-air mixture. They are so strong that they will resist internal explosions without damage and so tight that they will prevent the escape of flames or burning gases which might ignite the surrounding atmosphere.

Crouse-Hinds dust-tight lighting fixtures assure safety in locations that are hazardous because of the presence of combustible dust.

EV Series Explosion-Proof and Raintight Lighting Fixtures

DL Series Dust-Tight and Raintight Lighting Fixtures

. . . for Wet and Corrosive Locations

Crouse-Hinds vaportight lighting fixtures are ideal for use in boiler rooms, powerhouses, shower rooms, tunnels, loading docks, building entrances, and all indoor and outdoor locations where exposed to moisture and rain, non-explosive vapors and gases, or non-combustible dusts.

Hundreds of industrial lighting fixtures are listed in Crouse-Hinds Condulet Catalog.

Type MDR-14 Floodlight

V Series Vaportight and Raintight Lighting Fixtures

. . . for Protection

Sabotage thrives in darkness. The most reliable and cheapest form of protection against night prowlers is LIGHT! Crouse-Hinds floodlights project powerful beams of light that bathe all approaches to your property with glaring radiance, killing darkness and shadows and compelling everyone to be more visible at night than in broad daylight.

The protective power of light should be used in all important municipal and industrial locations. The floodlighting of industrial plants serves a double purpose. It helps to boost production in addition to the security it provides.

Send for your copy of Bulletin 2565, "LIGHT! Protect Your Property."

Type ADE-14 Heavy Duty Floodlight

Type DCX Searchlight

A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
Syracuse 1, N. Y.

Offices: Birmingham — Boston — Buffalo — Chicago — Cincinnati — Cleveland — Dallas Denver — Detroit — Houston — Indianapolis — Kansas City — Los Angeles — Milwaukee Minneapolis — New York — Philadelphia — Pittsburgh — Portland, Ore. — San Francisco Seattle — St. Louis — Washington. *Resident Representatives:* Albany Atlanta — Baltimore — Charlotte — New Orleans — Richmond, Va. CROUSE-HINDS COMPANY OF CANADA, LTD., TORONTO, ONT

CONDULETS · TRAFFIC SIGNALS · AIRPORT LIGHTING · FLOODLIGHTS

"UNION" *makes*

GEARS & PINIONS
TONGS & TONG LEVERS
UNIVERSAL COUPLINGS & SPINDLES
CHARGING BOXES
PEELS
SLAG POTS
INGOT CARS & CHARGING BOX CARS
SPECIAL UNIVAN & ARMOR
STEEL CASTINGS

Any mill superintendent who has used Union Castings will attest to their toughness. Built to last even under the most difficult operating conditions, these castings are made from high-strength steel that insures the very best in performance.

Tough stuff!

UNION STEEL CASTINGS

DIVISION OF BLAW-KNOX COMPANY, PITTSBURGH, PA.

This New Controller Says "Hurry Up, Furnace!"

WITH production reaching toward all-time highs, this new P.A.T. 50 Control already is helping many key plants increase the output of their furnaces. Here's why:

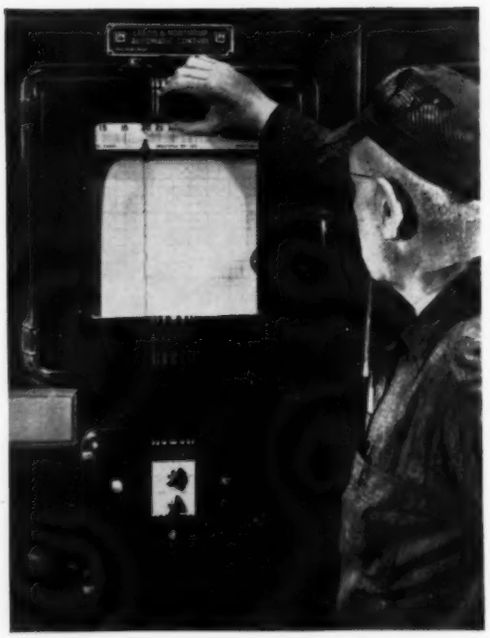
This Control has something that's brand new in proportional, electric controllers. Called "rate action," this feature enables the Controller to act on the *speed* of swings in furnace load, as well as on their size and on the length of time they persist. Thus, if temperature changes gently, it is gently nudged back into line. But if it starts off vigorously—as when the furnace door is opened—P.A.T. 50 reacts vigorously. Then, when the change has been headed off, the Controller starts to back away. But "putting on the brakes" it brings temperature in line smoothly and rapidly.

Thus, "Rate Action" increases production because it reduces the length of time a furnace is off temperature.

Also, Proportioning and Reset Actions are more responsive than before. These two components stop the normal temperature swings which are started by changes in the size and permanence of the furnace load. Even without rate action, these increases would enable P.A.T. 50 to do a better-than-ever job. With rate action, results are superior to any previous electric control.

The News is in the Control Unit at bottom of panel shown at right. Earlier installations can be converted to P.A.T. 50 by replacing the Unit and making slight changes in the Controller.

For details, contact our nearest office, or write us at 4942 Stenton Ave., Philadelphia 44, Pa.



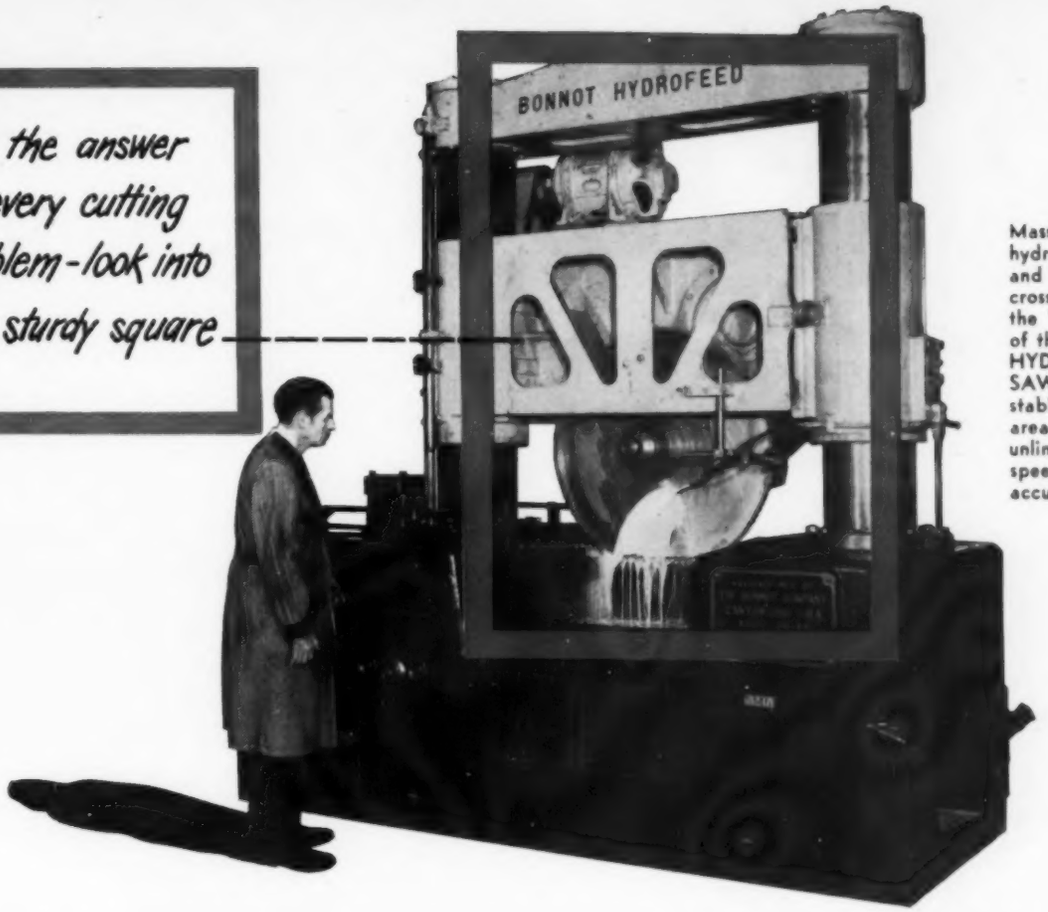
THESE furnaces and controllers are part of the slab-heating equipment with which The Timken Roller Bearing Company, Canton, O., conditions high-alloy steels for rolling. The Timken Company has used many earlier L&N Controllers. They find P.A.T. 50 is a further step forward, not only in guarding quality, but also in increasing production by shortening the off-temperature time.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND4-660(1)

For the answer to every cutting problem - look into this sturdy square



Massive base, huge hydraulic columns and one-half ton crosshead enclose the "sturdy square" of the Bonnot HYDROFEED COLD SAW. This assures stability of working area that means unlimited cuts at high speeds . . . perfect accuracy every time.

IT'S THE RUGGED HEART OF THE HYDROFEED BILLET AND BAR COLD SAW!

Engineered for continuous, 'round-the-clock performance—for a vastly stepped-up output and for "sharp pencil" economy — the *Bonnot* HYDROFEED COLD SAW stands alone in modern cold-sawing techniques and efficiencies. Automatic, high speed, vertical feed, it brings you a full "baker's dozen" of advantages unmatched by any other method!

Check these Features! Count them Too!

1. POSITIVE FEED CONTROL
2. ACCLIMATED TO ALL WEATHER
3. RIGID CONSTRUCTION
4. CHATTER-FREE OPERATION
5. SAFETY CONTROLS—FOR OPERATION AND MACHINE PARTS
6. ADJUSTABLE PRESSURE CONTROL
7. CUTS WIDE RANGE OF SIZES, SHAPES AND ANALYSES
8. PERMITS SELECTION OF FEEDS AND SPEEDS
9. PROVIDES HIGH VISIBILITY FOR OPERATOR
10. HIGH SPEED CUTTING AND CARRIAGE RETRACTION
11. SELF-CONTAINED HYDRAULIC SYSTEM
12. AUTOMATIC VOLUME CONTROL
13. EASY ACCESSIBILITY FOR MAINTENANCE

Now Get the WHY of Each Advantage

A Bonnot Engineer will be glad to show you how the "baker's dozen" of HYDROFEED features can be applied in your plant—profitably, effectively. Write, wire or phone today!

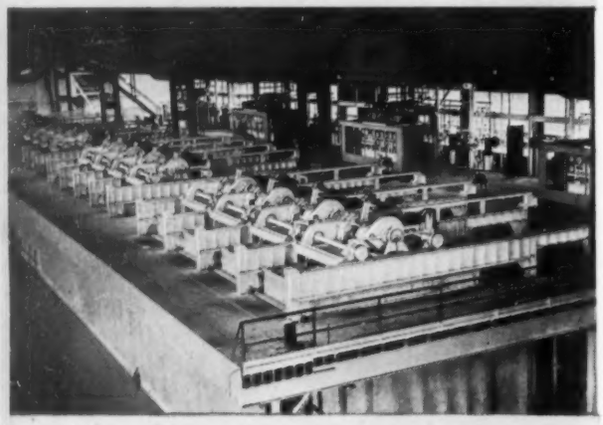
Engineered For Improved Production

The Bonnot Co.
STEEL EQUIPMENT DIVISION
CANTON 2, OHIO

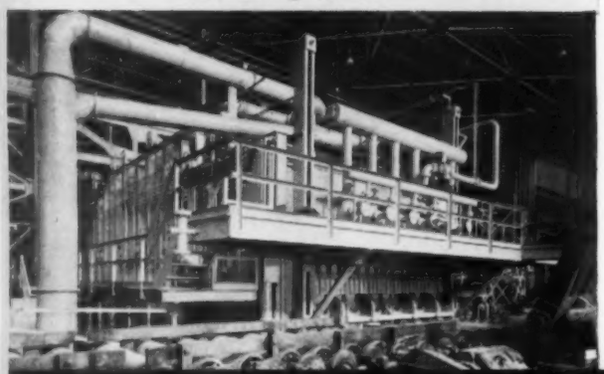
Also Manufacturers of — SAWING • CRUSHING • PULVERIZING AND MIXING EQUIPMENT • BILLET INSPECTION TABLES
DUST PUG MILLS • SINTER PLANT PUG MILLS

WHEN URGENT PRODUCTION SCHEDULES

One-way fired soaking pits.



Slab heating furnaces.



• Steel-makers who must increase tonnage and maintain quality, to meet urgent demands, find 'Surface' heating and heat treating equipment superbly suited to their needs.

And here's why: Scores of operating and engineering executives in the metal producing and metal working industries, in cooperation with 'Surface' engineers, helped build 'Surface' equipment. Continuous laboratory research in scientific application of gases, heat and mechanisms to many heating problems have netted improved 'Surface' equipment that *produces*—dependably and economically—year after year. Into each installation goes the know-how accumulated by men who have spent their lives in working in and with the steel industry. Now, when prompt, quality tonnage is vital, 'Surface' offers modern processes and methods that *deliver the steel.* Write us today.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

FOREIGN AFFILIATE COMPANIES

BRITISH FURNACES LIMITED—CHESTERFIELD
STEIN & ATKINSON, LTD.—LONDON
STEIN & ROUBAIX—PARIS, LIEGE AND GENOA
WILL L. SMITH, S.A.—BUENOS AIRES

'Surface' SERVES THE STEEL INDUSTRY

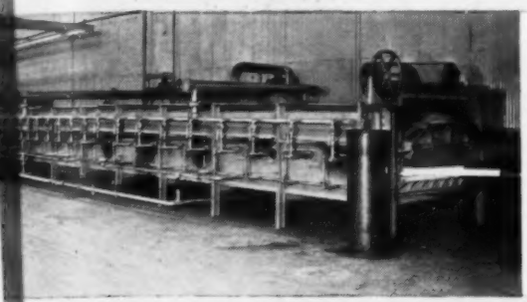
One-Way Fired Soaking Pits • Billet Reheating Furnaces • Slab Heating Furnaces • Continuous Type, Controlled Atmosphere Strip Annealing and Normalizing Furnaces • Controlled Atmosphere Annealing Covers for Wire and Rod • Controlled Atmosphere Annealing Covers for Coil and Sheets • Continuous Furnaces for Heat Treatment of Steel Plate • Controlled Atmosphere Furnaces for Carbon Correction in High Alloy Rod and Bar Stock • Continuous Type Bright Annealing and Normalizing Furnaces • Prepared Gas Atmosphere Generating Equipment • Pit Type Convection Furnaces for Rod Annealing • Stress Relief Furnaces • Wire Patenting Furnaces

DEMAND

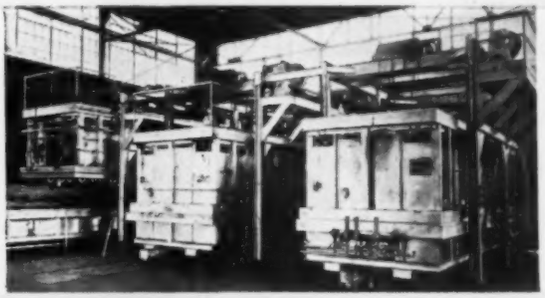
heat

FROM INGOT THROUGH FINISHED PRODUCT

Wire patenting furnaces.

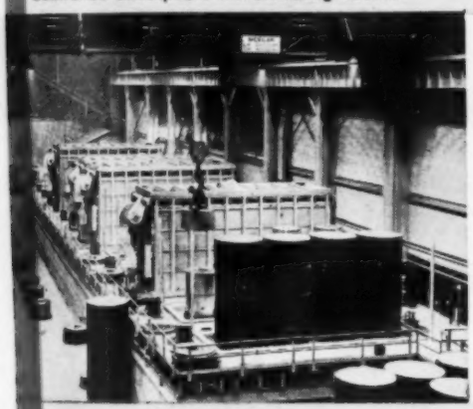


Batch type carbon correction annealing furnaces.



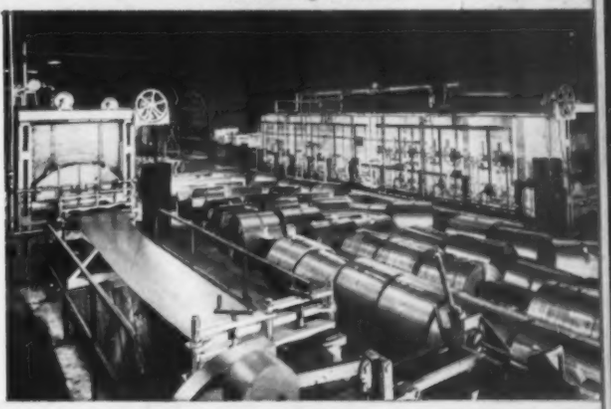
Continuous bright annealing and normalizing furnaces for tubing.

Controlled atmosphere coil annealing covers.

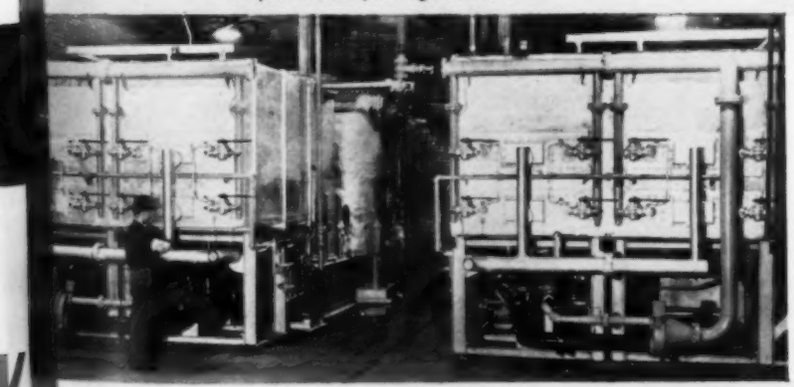


Pit type convection furnaces for rod annealing.

Continuous strip annealing and normalizing furnaces.



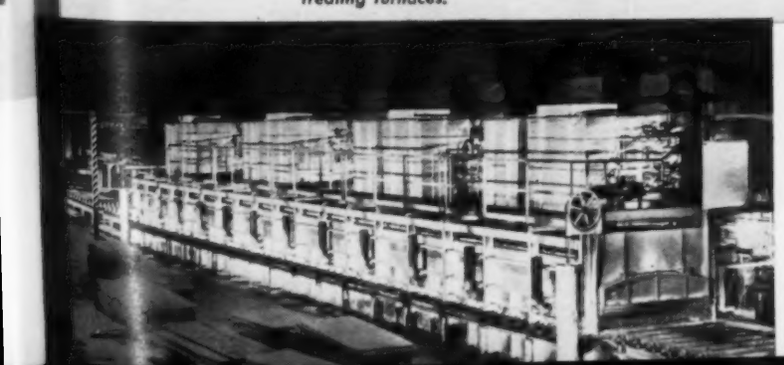
Prepared atmosphere generators.



Stress relief furnaces.

Continuous controlled atmosphere annealing furnaces.

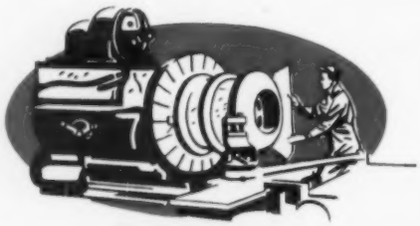
Continuous armor plate heat treating furnaces.

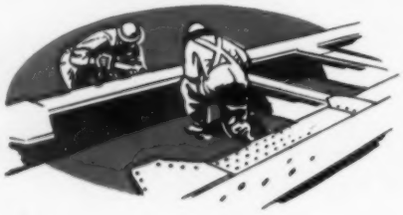


Controlled atmosphere wire and rod annealing covers.

"It ain't the individual nor the army as a whole
But the everlastin' teamwork of every bloomin' soul."

Excerpt from "Cooperation"
by J. Mason Knox





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Crops and Shorts

ACCORDING to the American Iron and Steel Institute, approximately 93,000,000 net tons of metals in all forms were shipped by domestic producers to consumers in 1950. This includes 72,200,000 tons of steel products, more than 15,000,000 of cast iron and cast steel, and 5,100,000 tons of aluminum, copper, brass, lead and zinc.

In 1950, steel production in the United States averaged 1274 lb of ingot steel per capita. The output per capita in other countries was approximately as follows: Belgium, 958 lb; Great Britain, 721 lb; West Germany, 554 lb; Canada, 488 lb; France, 445 lb; Russia, 275 lb; Japan, 117 lb.

▲

IF you're statistically minded, you might be interested to know that the United States is consuming cigarettes at a rate of 410,000,000,000 per year, and last year spent $8,760,000,000 for liquor, wine and beer.

▲

ALL six of the major steel producing districts are participating in the general increase of steel capacity. Figures released by the American Iron and Steel Institute show district capacities as follows at the start of each year indicated:

District	Millions of Tons (Per cent of total)		
	1939	1951	1953
Pittsburgh (incl. Youngstown and most of Ohio Valley)	34.9 (42.7)	41.4 (39.7)	45.0 (38.2)
Chicago (Ill., Ind., Minn., Wis., and Mo.)	18.0 (22.0)	21.5 (20.7)	23.9 (20.3)
Cleveland (incl. Michigan)	7.8 (9.5)	9.6 (9.2)	12.0 (10.2)
Western	2.1 (2.6)	5.9 (5.7)	6.7 (5.7)
Southern (Va., Tenn., Ala., Ga., Okla., and Texas)	2.8 (3.5)	4.9 (4.7)	6.0 (5.1)
Eastern (Md., Del., N. J., N. Y., Conn., Mass., R. I., and eastern Pa.)	16.1 (19.7)	20.8 (20)	24.2 (20.5)
Total	81.8	104.2	118.0

AND another statistic informs us that at the start of 1951, the country's motor truck fleet totaled over 8,600,000, as compared with 4,600,000 units a decade earlier. We still think there are more than that, unless they all pick the same time and same highway on which we are driving.

▲

CERTIFICATES of necessity, granting rapid amortization of expenditures for new industrial expansion, have tapered off quite abruptly. Approximately 1660 certificates have been approved, covering expansion projects estimated to cost almost $6,000,000,000. A recent grant to McLouth Steel Corp. covers a major expansion which will make the company an integrated unit.

▲

TIMES have certainly changed. A woman used to go to a doctor to see if she could have children; now she goes to the landlord.

▲

ARMCO STEEL CORP. has introduced a novel (and psychologically smart) idea in awarding gold brooches to the wives of men who have worked 25 years or more with the company.

▲

PROPOSALS are cropping up in various states for a constitutional amendment prohibiting the Federal government to take more than 25 per cent of an individual's or a company's income, except in times of national emergency. Apparently giving no thought to reducing non-essential spending. Treasury officials say such a limitation would lead to a continuing deficit. They argue that present tax rates on large individual incomes do not affect very many people, anyway. This is typical of the thinking of today's politicians, ignoring justice and injustice, and considering only the number of potential votes involved.

But should such a ceiling be imposed on the Federal "take," we'd take a little bet that, since the limitation would be set aside in periods of national emergency, we'd never have another moment's peace.

▲

IN order to assure its manufacturing operations of a supply of steel, the R. G. LeTourneau, Inc., is building a steel plant at Longview, Texas. The plant, which will include two 25 ton electric arc furnaces and a plate mill, is estimated to cost $1,000,000, part of which is covered by a certificate of necessity. General Motors Corp. is attaining much the same end by lending substantial sums at low interest to Republic and Jones & Laughlin for their expansion projects. The loans will be repaid through the delivery of steel products.

▲

A NEW world rolling record — 200,812 net tons — was established in May by the 45 in. slabbing mill at Homestead works of United States Steel Co. At the same time, the company set a new monthly record in steel production, when 2,056,262 tons of ingots came from the furnaces of its Pittsburgh and Chicago district plants.

▲

WHY do they call it the rush hour, when traffic is jammed to a stand still?

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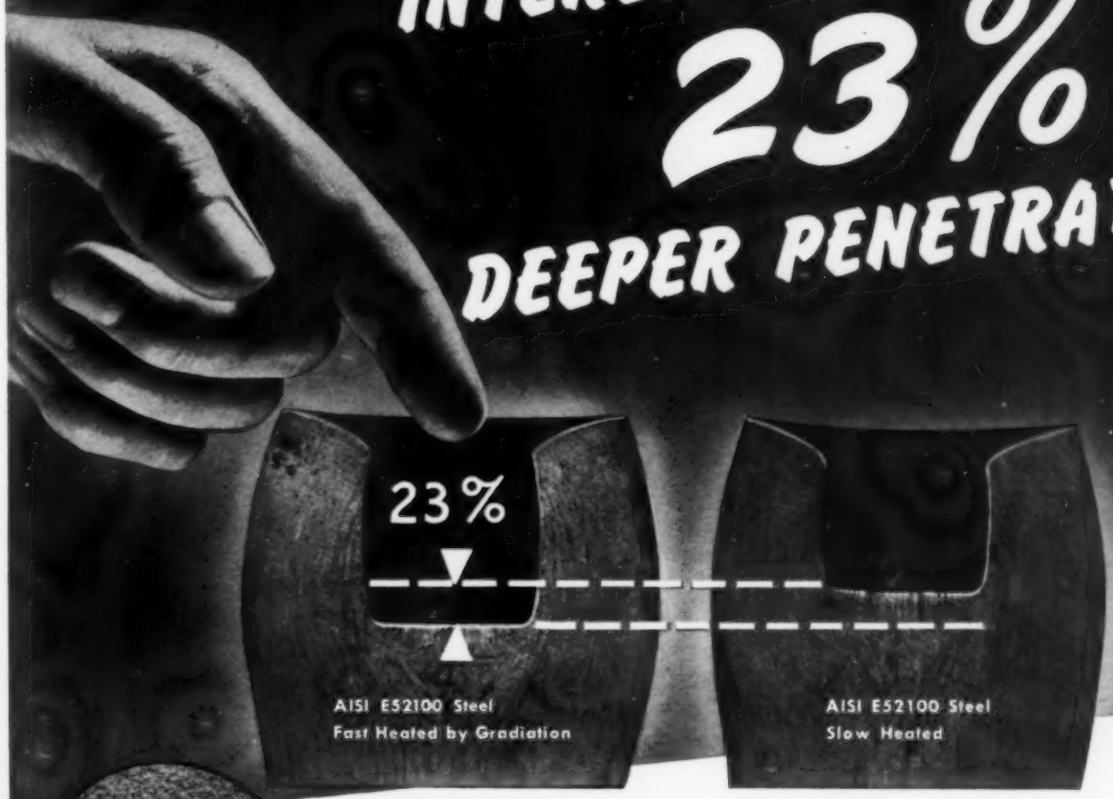

Grain size in AISI E52100 after rapid heating with Gradiation

Grain size in the same steel after conventional heating cycle

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Improves Metal Flow . . . Retards Grain Growth

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Iron and Steel ENGINEER

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MOORE RAPID

WHEN YOU MELT... *Lectromelt*

METALLIC RECUPERATORS
for Slab Heating Furnaces

By R. R. SHEDD
Design Engineer
Construction Engineering Bureau
United States Steel Co.
Pittsburgh, Pa.

. . . . the use of metallic tube recuperators offers promise of lower fuel consumption, better operating control of temperature and lower maintenance costs than the ceramic type units . . . .

▲ AT the conclusion of World War II, the flat rolled steel products market entered a period of high demand activity unparalleled in the history of the industry, indicating the existence of a substantial margin between consumer purchasing level and industrial production. To rectify this situation, immediate steps were undertaken to increase the efficiency of various manufacturing units and authorize new facility construction. One phase of this modernization program was the erection on existing sites of eight new continuous slab heating furnaces in the Chicago district of the United States Steel Co.

Five new, high capacity, triple-zone, continuous furnaces were installed on an 80-in. hot strip mill, each having a nominal rating of 105 gross tons per hour. Three new furnaces of somewhat similar design were added to an existing furnace on a 96-in. plate mill, these furnaces having a nominal rating of about 65 gross tons per furnace hour. The decision to install a row of five slab heating furnaces on the 80-in. hot strip mill was predicated on the forecasted market demand, and was coupled with other important improvements to mill stand drive motors and gear sets, three new coilers, and various alterations to auxiliary equipment. Heating capacity and rolling rate had to be balanced on this mill to realize the full potentialities of a high production unit. Experience at this plant and throughout the industry indicated that slab heating furnaces more frequently than not paced the rolling mill and thereby comprised the bottleneck to economical production. Insufficient heating capacity prevented or curtailed proper furnace maintenance and contributed to comparatively high heating costs and increased outage time.

The three furnaces originally installed on the 80-in. hot strip mill (1935 and 1936) had a nominal rating of 67 gross tons per furnace hour. The recuperators on these furnaces were of refractory tile construction and remained in operation about one year. Subsequently, when the replaced recuperators were found serviceable for only one and one half years, these furnaces were operated without any recuperation of the combustion air, which practice contributed to high fuel costs and generally unsatisfactory furnace operations. In the interim between initial furnace operation and abandonment of recuperation, several changes were made in an attempt to modify the original design, but it became apparent that maintenance costs of the recuperators would exceed any possible savings. The furnaces at this time definitely restricted high production rates due to excessive leakage and draft restriction. The removal of the recuperators permitted higher flue drafts and thereby increased furnace heating rates. Essentially, the same conditions prevailed with regard to the furnaces serving the 96-in. plate mill.

When the modernization program was authorized in 1945, the decision was made to install metallic tube type recuperators on all five slab heating furnaces on the 80-in. hot strip mill. The economics of delivering heated air to furnace burners is well established, providing an incentive for the use of recuperators. Secondly, alloy steels developed for good service characteristics at elevated temperatures had been successfully proven over a period of years. Finally, the engineering principles incorporated in the metallic tube type recuperator, tested in actual service to a limited degree, appeared to have reached a stage of development making its application to these furnaces mandatory. Experience over the ensuing period of operations indicated that further use of the metallic recuperator was in order, and accordingly the new furnaces on the 96-in. plate mill were so equipped when at a later date these three furnaces were purchased.

The five slab heating furnaces on the 80-in. hot strip mill are designed to heat slabs with coke oven gas firing, but operated to date on fuel oil, natural gas, or a combination of these fuels depending on availability. Slab sizes range from 3½ to 7½ in. in thickness, 18 to 60 in. in width, and 9 to 18 ft in length. The effective heating length of these furnaces is 80 ft, with an inside hearth width of 20 ft and an exterior width, 23 ft, 9 in. The soaking hearth is 16 ft, 9 in., in length, having a total hearth area of 335 sq ft. It was estimated that

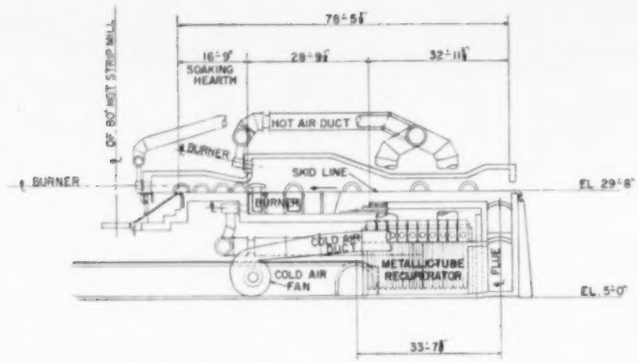


Figure 1 — Longitudinal section of 80-in. hot strip mill furnace.

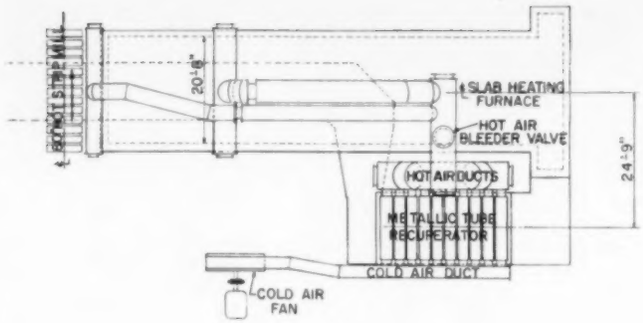


Figure 2 — Plan of 80-in. hot strip mill slab heating furnace.

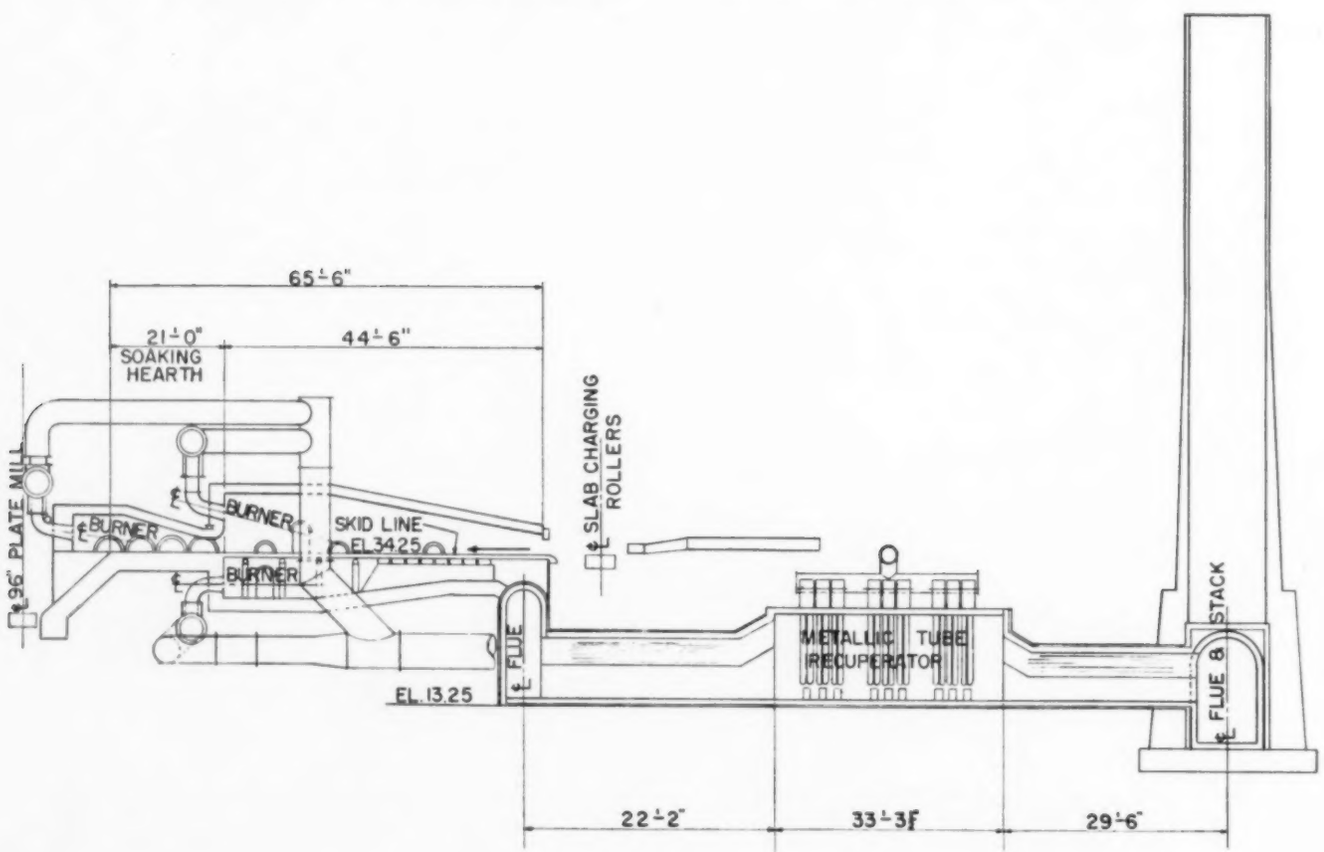
fuel consumption would amount to 1,650,000 Btu per gross ton heated with a rolling rate of 105 tons per hour and a delivered slab temperature of 2350 F was attained, using 700 F combustion air.

Recuperators for the 96-in. plate mill furnaces were designed to heat approximately 20,000 cfm of air to a temperature of 800 F. The over-all effective heating length of these latter furnaces is slightly under 60 ft and hearth width is 16 ft. Length of the soaking hearth is 16 ft, equivalent to 256 sq ft. As a further comparison, hearth coverage averages about 93 and 82 per cent for the 80-in. hot strip mill and 96-in. plate mill furnaces, respectively.

Figure 1 is a section diagram of the furnace profile for the 80-in. hot strip mill furnaces, showing location of the main furnace components, including the downcomer or waste gas flue at the entry end of the furnace and the recuperator installed on close centers to the downcomer. After passing through the recuperator, the waste gases are exhausted out below the furnace proper and the slab entry tables to the mill, and into stacks located outside the building area. One stack is provided per furnace. This drawing also shows the cold air fan located at the same elevation as the base of the recuperator. Hot air ducts leading to the three heating zones are also shown.

Figure 2 is a plan sketch of the same furnaces, showing in particular the method of locating the recuperator in an accessible position. Fan and portions of the combustion air ductwork entering and leaving the recuperator are also shown. Note especially from this sketch that the entire combustion air system is placed under

Figure 3 — Longitudinal section of 96-in. plate mill furnace shows a different location for the recuperator.



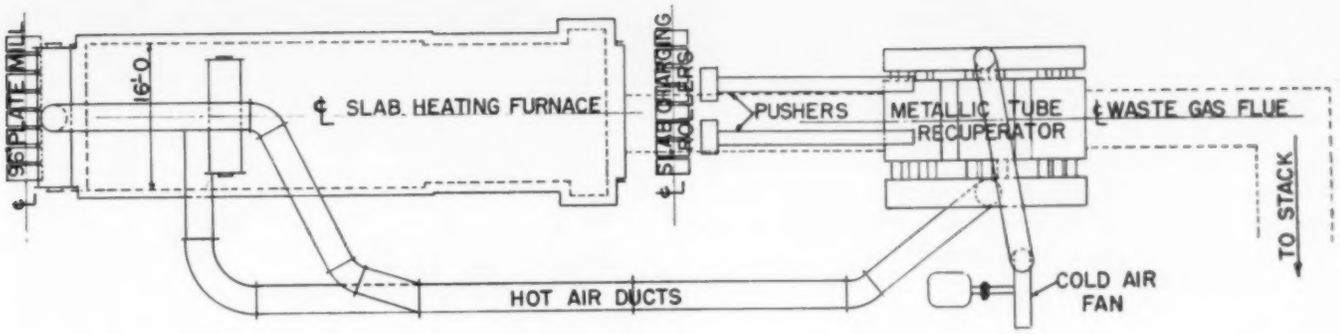
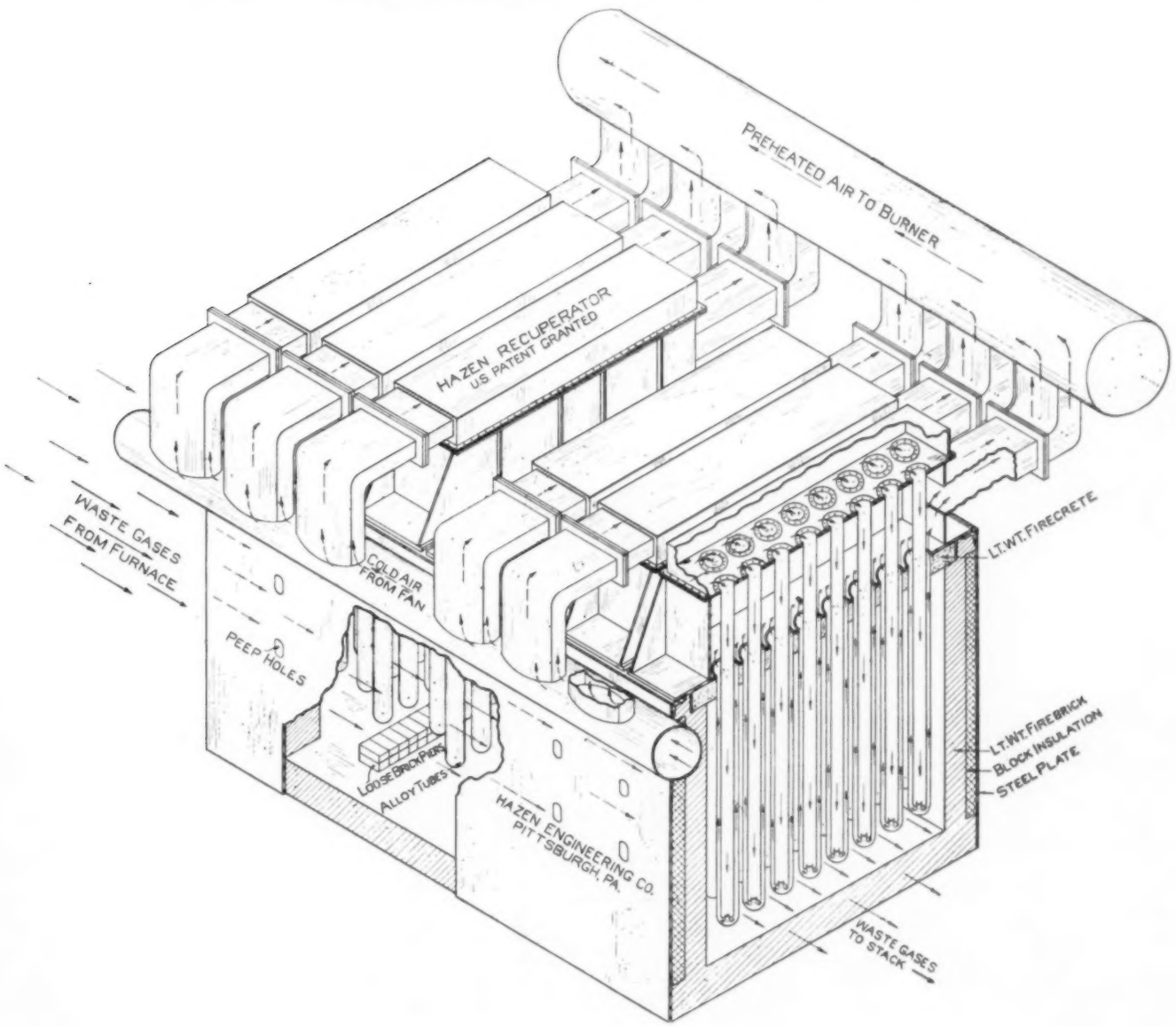


Figure 4 — Plan of 96-in. hot strip mill furnace.

positive pressure. The fan is also located in an accessible position and the air handled by the fan is at a normal or building temperature.

Furnaces built for the 96-in. plate mill differ considerably in physical dimensions from the units described above, as the building space available for this installation dictated a much shorter over-all length. Triple-zone heating design is utilized, employing principally natural gas with fuel oil as stand-by. Figure 3 is a profile diagram of these furnaces, showing the location of the recuperator with respect to both furnace and stack. One recuperator is provided for each furnace.

Figure 5 — This type of recuperator was used on the 96-in. plate mill furnace.



A plan sketch of the latter furnaces is shown on Figure 4. Here again, it will be observed that both the recuperator and fan are located in an open area to facilitate access.

An isometric drawing of the design and type of recuperator provided for the 96-in. plate mill furnaces is presented and identified as Figure 5. An over-all length of 33 ft, 3 in., is required for these recuperators. Width is 10 ft, 8 in., and height is 14 ft, 7 in. The earlier installation on the 80-in. hot strip mill is somewhat more compact as regards length, but larger in width and height. The additional length of the newer recuperator on the plate mill furnaces is due to the desirability of increased spacing between banks of tubes. Recuperators on the strip mill furnaces are 23 ft, 8 in., in length, 13 ft, 6 in., in width, and 14 ft, 7 in. in height. These dimensions are presented to demonstrate the general size of these particular installations but are variable for each new installation.

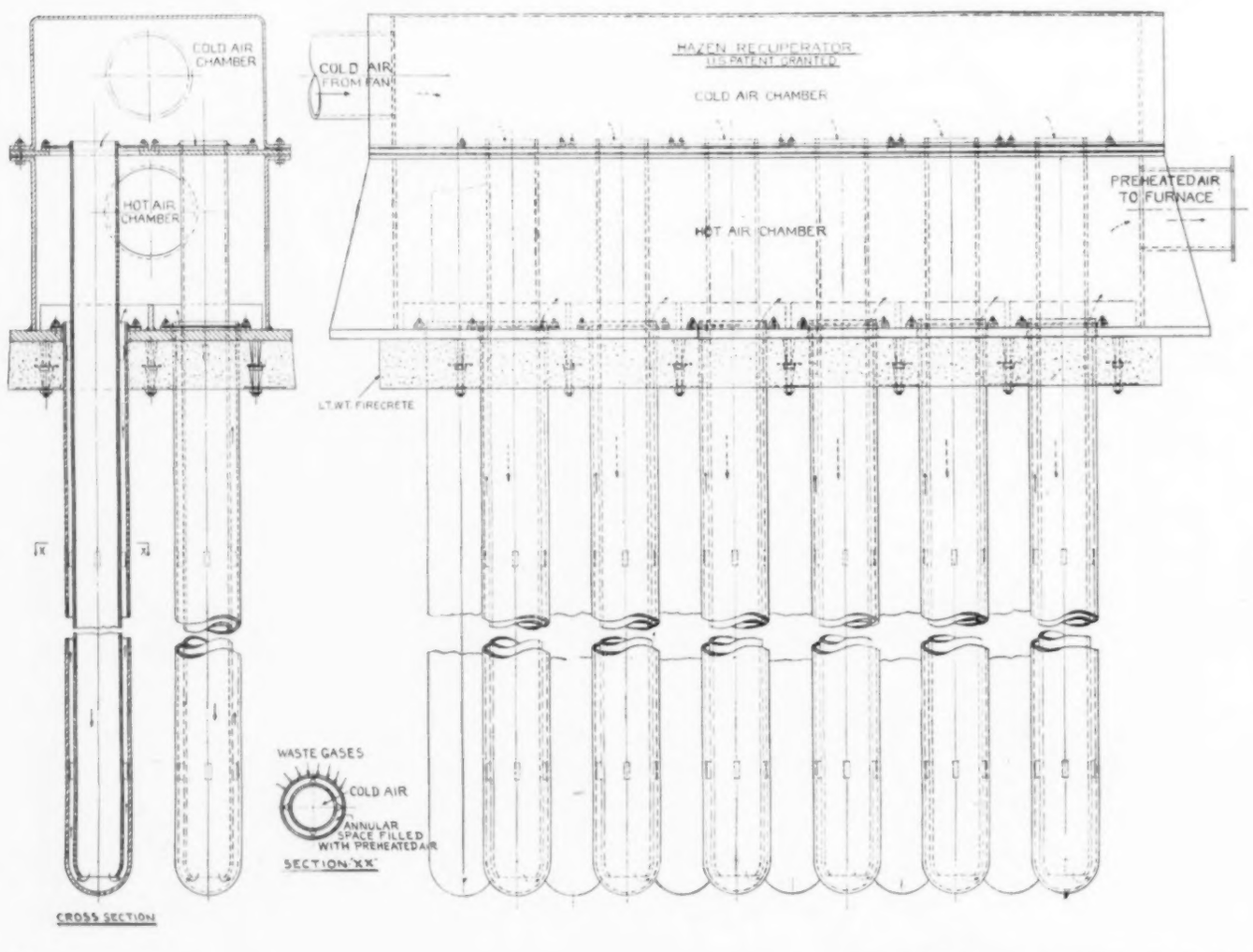
The construction and design features of the metallic-tube type recuperator as shown on Figure 5 achieves constant delivery of combustion air at controllable temperature, volume, and pressure, all three being extremely important for automatic operation of this type of slab heating furnace. Placing the recuperator directly in the waste gas flue and as close as feasible to the furnace materially benefits heat recovery efficiency, as the flue gases are at the highest temperature and the air ducts to the burners are shortened accordingly. It is unnecessary to provide a by-pass waste gas flue around the recuperator, as experience has indicated that the type of repairs involved with this type of recuperator are usually of such a nature that furnace operation is rarely interrupted as a result of recuperator failure.

The chamber containing the recuperator is normally designed with a relatively large cross-sectional area, thus reducing the velocity of waste gases contacting metal tube surfaces. Fabricated of structural steel and lined with suitable firebrick and insulating refractories, the life of recuperator flue side walls and base pad has presented no maintenance problem to date, as would be anticipated in view of the service conditions as to gas temperature.

The main components of the recuperator consist of hot air and cold air plenum chambers, heat transfer tubes, motor-fan unit, cold air duct, and insulated hot air ducts, together with thermal control instrumentation. Engineering design for the various equipment is varied according to required capacity.

Stainless steel is used for all exterior tubes, usually of the 25 Cr-12 Ni type on the first two or more rows of tubes where temperature service conditions are severe. Subsequent rows of tubes frequently employ a grade

Figure 6 — Sketch shows detailed arrangement of the tubes and illustrates how they are hung.



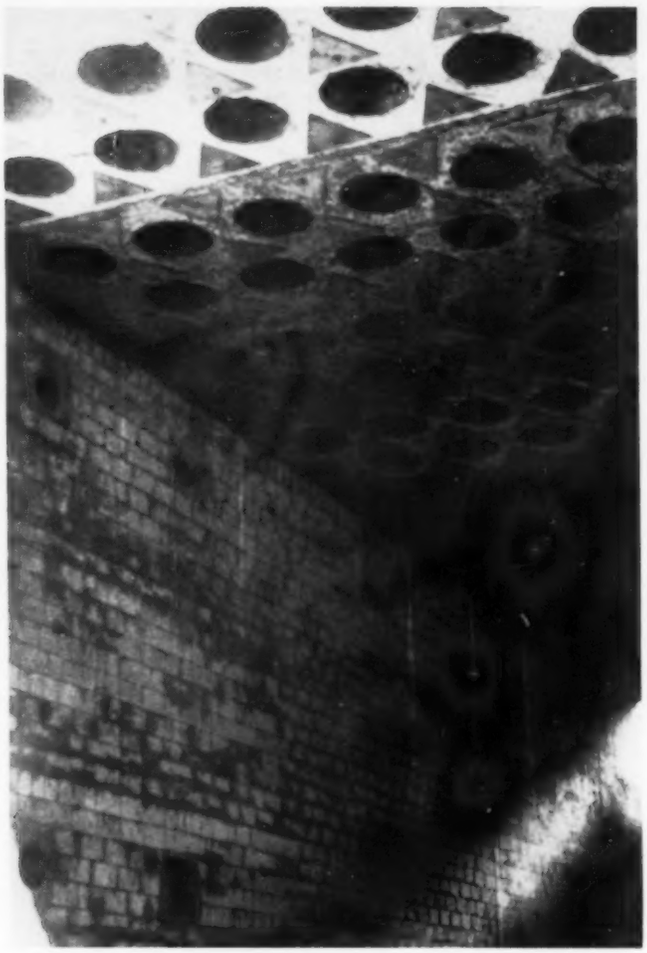


Figure 7 — The bottom of the hot air header box is shown prior to inserting the tubes.

suitable for lower service temperature. The tubes are fabricated from hot rolled, pickled, and annealed stainless sheets, formed into a cylinder and the joint welded. The cold air box is fabricated of carbon steel, while the hot air box and various metal components exposed to the heated air are made of stainless steel. Outer tubes are located with the seam weld 180 degrees from the direction of the incoming flue gases. Exterior tubes in the first two boxes contacting flue gases are made of relatively heavy gage stock, while the balance of tubes in the remaining boxes and all inside tubes are made of somewhat lighter gage.

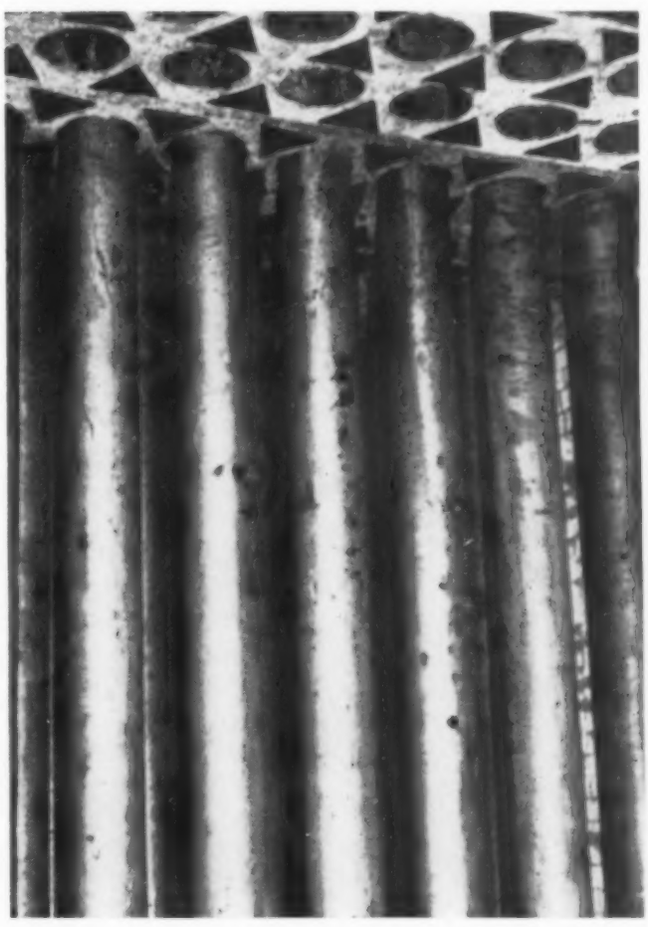
The recuperators on the 80-in. hot strip mill consist of ten boxes, each box containing a total of 20 heating elements, ten tubes wide and two tubes in length, making a total of 200 tubes or heating elements per recuperator. Recuperators for the 96-in. plate mill furnaces were designed with nine boxes of tubes, each box containing two rows of eight tubes each, making a total of 144 tubes. The number of tubes is obviously a function of operating conditions and service requirements, as is also the length, diameter, annulus dimension, tube gage, et cetera.

The cold air enters the plenum chamber at the top of the recuperator and flows downward through the inner tubes, entering the outer hot tubes at the bottom and flowing upward to a hot air plenum chamber into the main air header, and thence to the burners. The rate of flow of air in the annulus between the inner and outer tubes is very high and has an obviously high wiping and heat transfer characteristic. The design of the annulus and the volume of air forced through the annulus is varied according to the severity of anticipated service conditions. Hence, there is a difference in annulus dimension and air flow velocity in the two rows of tubes in the box or boxes first contacting the hot flue gases. Tubes installed in succeeding boxes are designed for a lower temperature flue gas.

Several features of design are worth further commentary. As mentioned previously, the fan delivering the air to the recuperators and thence to the burners, is blowing comparatively cold air and no special precautions are necessary in design to protect the motor and fan as would be necessary if hot air were being handled. The fan installed here is a 7.25 ft, self-limiting type fan, having a capacity of 45,000 cfm at 20 in. static pressure. Directly connected to the fan is a 200 hp, 365 rpm motor. Recuperators on the 96-in. plate mill furnaces are equipped with fans having a capacity rating of 24,000 cfm at 6¾ in. static pressure, powered by 100 hp, 732 rpm motors. Suspension of the tubes from the top permits expansion and contraction due to temperature differentials with no strain on the metal. Brick piers or baffles are placed on the bottom of the recuperator flue to deflect the waste gases against the tube surfaces and thus to prevent bypassing or streamlining of the flue gases below the tubes.

Possibly one of the most important aspects of this

Figure 8 — Some of the tubes have been hung in this view.



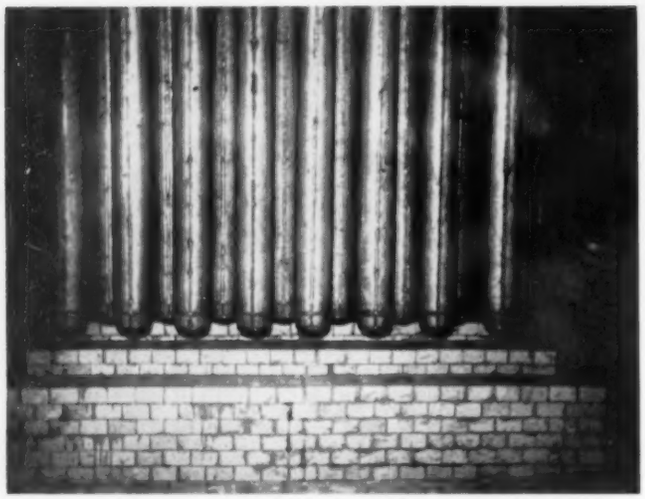


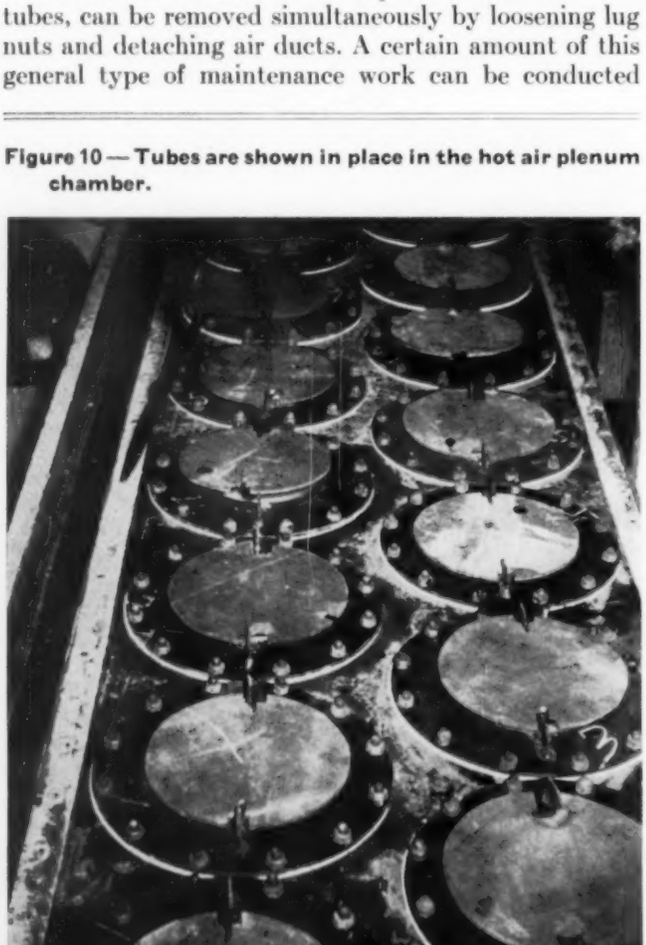
Figure 9 — This photograph is taken from the exhaust end of the recuperator.

type of recuperator besides that of performance, is the ability to maintain the tubes in an operable condition. Removal of tubes for inspection or replacement is facilitated by this design. The cold air plenum chamber is removed first, exposing the inner tubes which can be lifted vertically. The exterior tube is then accessible and is removed vertically without disturbing the balance of the box. On the other hand, the entire box, inclusive of both hot and cold plenum chambers and tubes, can be removed simultaneously by loosening lug nuts and detaching air ducts. A certain amount of this general type of maintenance work can be conducted without interrupting delivery of heated combustion air to furnace burners, although it is advisable to maintain a flow of air through the tubes during furnace operation and in the interval immediately following operation. Tube protection from radiant heat energy is also afforded with this precaution.

Figure 6 further clarifies the arrangement of each box in the recuperator. This drawing illustrates the method employed in suspending the tubes from the top, thereby permitting free expansion and contraction as occasioned by thermal changes. Attention is directed to the use of asbestos gaskets to effectively seal the flange of the tube against leakage. Stud bolts and nuts, securing the tube to the base of the plenum chamber, are stainless steel in the hot air box. Clearance is sufficient in the base of the cold air plenum chamber base to permit withdrawal of the hot air tubes.

Figure 7 pictures the recuperator flue and the bottom of the hot air header box prior to inserting the tubes. The waste gas flue enters on the right (not shown) and is exhausted at the extreme end of the recuperator flue (lower left corner of photograph). Figure 8 is taken from the entry end of the waste gas flue with the tubes in the first box uninstalled. Note that the refractory material is suspended from the base plate of the hot air plenum chamber with the use of stainless steel bolts and triangular washers. Figure 9 is a photograph taken from the exhaust end of the recuperator and shows the location of the weld and the brick piers or baffles in place. Figure 10 shows the tubes in place in the hot air plenum chamber. Sealing design is apparent in this photograph. Tube ends are covered to prevent collection of building materials during construction.

Figure 10 — Tubes are shown in place in the hot air plenum chamber.



Under maximum heating requirements, combustion air demand for all three zones totals about 35,000 cfm. Air temperatures in the main headers vary from 650 F to 725 F and average about 700 F. The temperature of the flue gases entering the recuperator average around 1800 F and about 1200 F leaving the recuperator. With air temperatures of 700 F, fuel consumption per net ton of steel heated has averaged 1,700,000 Btu, a significant decrease in fuel consumption when compared to the original three slab furnaces consuming approximately 3,000,000 Btu or more per ton of steel heated. Much of the improvement in efficiency is attributed to automatic furnace controls, but it is believed that without recuperation of the combustion air, furnace capacity would be restricted by about 10 per cent.

Air temperatures have ranged somewhat higher on the furnaces for the 96-in. plate mill. Air volumes of around 20,000 cfm are required during peak heating requirements and average between 800 F to 925 F in temperature. Flue gases frequently range as high as 2000 F entering the recuperator and between 1100 and 1200 F leaving the recuperator. Here again, fuel consumption has been reduced to around 2,000,000 Btu per ton of steel heated from a high of 3,500,000 Btu per ton before dismantlement of the old furnaces.

Typical temperature charts which were obtained from two consecutive operating turns covering a period of sixteen hours are shown consecutively in Figure 11. Thermocouples numbered 1 to 9, inclusive are located in the hot air plenum chambers, these temperatures appearing as the lower nine lines on the charts. Thermocouples numbered 10 and 11 measure waste gas tem-

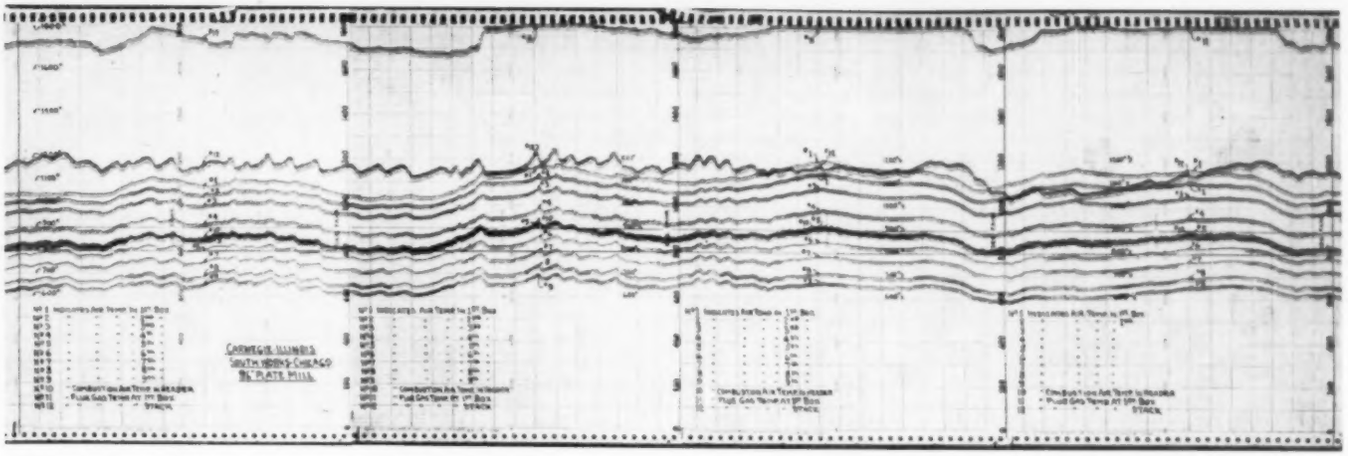


Figure 11 — Operating record covers period of 16 hours.

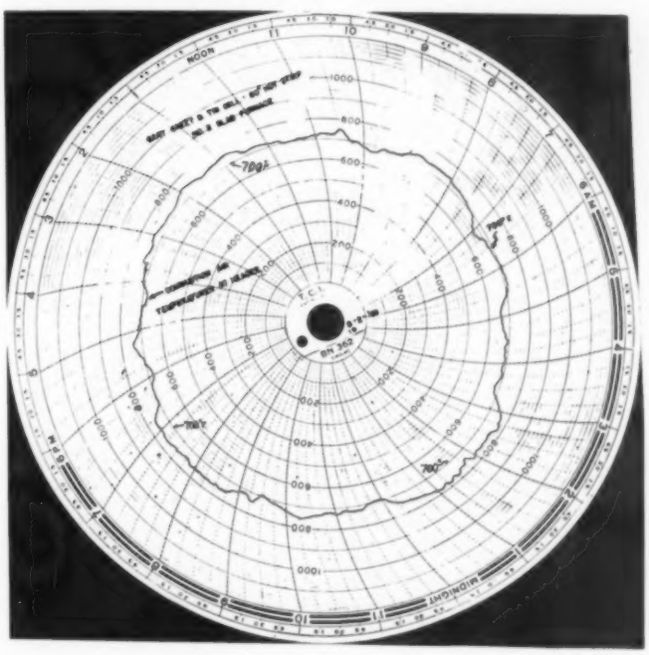
peratures entering and leaving the recuperator, respectively. The temperature of combustion air in the main headers connected to the burners is identified as the number 12 thermocouple and is shown by the broad line superimposed on the number 5 couple reading. These temperature data are indicative of normal thermal recovery obtained with the metallic tube recuperator. A typical combustion air temperature chart is shown on Figure 12 and demonstrates temperature control during a normal twenty-four hour period.

The normal combustion air temperature is controlled to maintain approximately 700 F and 800 F on the burner header of these two installations by opening a bleeder valve to the atmosphere on the hot air delivery of the recuperator and passing sufficient air through the recuperator to limit air temperature to the control setting. As a precaution against overheating, an emergency air temperature control is also provided, having the thermocouple located in the hot air outlet of the first box of the recuperator. The temperature established for the emergency temperature control is set at 925 F for the 80-in. hot strip mill, and 1015 F for the 96-in. plate mill, and should the temperature of the combustion air exceed this limit, the hot air bleeder will further open to limit the air temperature to the maximum setting, regardless of whether or not normal furnace capacity is obtained.

During periods of low heating rates, a minimum flow of using 50 per cent of fan capacity is maintained through the recuperators, and is released through the bleeder valve. This minimum flow rate was arbitrarily established to prevent the possibility of tube damage resulting from heat radiation from adjacent brickwork in instances of sporadic furnace operation.

During the winter months, 100 per cent heavy fuel oil is used due to curtailment of natural gas. In the winter of 1947-1948, the 80-in. hot strip mill furnaces experienced a gradual reduction in effective furnace draft and air preheat temperature. An investigation of the recuperators disclosed that a heavy insulating type deposit was collecting on the outside tubes in the direction of the incoming flue gases, thereby causing a restriction in furnace draft and effecting thermal conductivity of metal surfaces in the recuperator. Chemical analysis of the deposit revealed that the build-up was calcium sulphate, an impurity contained in certain so-called "sour" fuel oils. Certain oil distilleries practice neutralization of high sulphur bearing oils by passing the oil through towers containing lime or dolomite, thus neutralizing the action of sulphuric acid which would corrode various oil handling facilities. Oils thus produced contain sulphate salts of calcium and magnesium, as the case may be. The compound is then volatilized at furnace temperatures and condensed on the cool surfaces of the recuperator tubes. Experience in open hearths and other recuperative or regenerative fuel oil burning installations is very similar to that obtained here with respect to the deposition of the salt on cold surfaces. Where refractory tile or carborundum tubes are employed, removal of the deposit is entirely unfeasible. The 80-in. hot strip mill furnaces were subsequently shut down, the recuperator tubes cleaned, and boxes No. 3 and No. 7 removed from each recuperator to increase furnace draft and facilitate more frequent inspection and cleaning. The weirs located in the bottom of the recuperator were reduced also. At

Figure 12 — Chart shows good temperature control.



the same time, the contract oil suppliers were approached on the problem and arrangements were made for the provision of calcium sulphate free fuel oil. Horizontal arrangement of recuperator tubes would increase the problem of removing deposits from tube surfaces.

The change in fuel oil has eliminated the deposit problem. The forty heating elements removed in boxes No. 3 and No. 7 have had some effect on recuperator efficiency, but the operators are well satisfied with the present performance. Previous to cleaning and removal of tubes, the draft loss of flue gas through the recuperators averaged approximately 1.2 in. water, compared to an average after cleaning of approximately 0.6 in. water.

In conclusion, it may be stated that a sufficient time interval has elapsed since the initial installation to evaluate the effect of the metallic recuperator on furnace efficiency and production. The advantages appear to be: (1) close operating control of temperature and pressure, permitting satisfactory utilization of fully automatic instrumentation and control on a slab heating furnace; (2) economical recovery of the heat value from flue gases and increased efficiency of heating; and (3) low outage and maintenance costs. Fuel consumption is believed to be lower than in slab heating furnaces employing other types of recuperators.

DISCUSSION

PRESENTED BY

FRANK D. HAZEN, President, Hazen Engineering Co., Pittsburgh, Pa.

Frank D. Hazen: I would like to stress one point. The use of recuperators in the past has been looked upon from the standpoint of fuel savings alone, which with the constant increase in the price of fuel is still a vital factor. However, the increase in tonnage derived from this metallic recuperator is a major consideration and should not be overlooked.

I noticed that some of the gentlemen present at the meeting raised their eyebrows when Mr. Shedd mentioned the capacity of the fans and motors used in connection with the slab furnaces for the 80-in. hot strip mill at Gary. This point I want to make clear. The application of this recuperator does not necessitate the use of an oversized fan. These fans at Gary were designed for 50 per cent additional air capacity and for a pressure of approximately twice what is generally used with this recuperator. Most operators feel that additional fan capacity is advantageous, regardless of whether or not a recuperator is used.

Plan to attend!

Annual Convention

Association of Iron and Steel Engineers

October 1, 2, 3 and 4, 1951

Hotel Sherman

Chicago, Illinois

Acceleration Characteristics of Tandem Cold Reduction Mills

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Metal Working Section
and
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. . . . a new concept in design of tandem mills is that of "acceleration lag" . . . . this enables a better approach to mill drive design than "acceleration torque" . . . .

▲ THE first tandem cold reduction mill was designed and installed in 1928. This was a four-stand, 32-in. wide mill, with a maximum rolling speed of 340 fpm and a total horsepower of 1020 for the mill and reel motors. The speed and power of tandem cold reduction mills has increased at a phenomenal rate since that time. Table I gives the data on the speeds of twenty-six cold reduction mills either installed or revamped for higher speeds since 1945. The column labeled average is the average of all mill speeds and is typical of the average mill. For instance practically all of the four-stand mills have been designed for speeds around 3000 fpm, with only one mill much below this value.

TABLE I

Type of mill	Number of mills	Minimum speed, fpm	Maximum speed, fpm	Average speed, fpm
3-Stand	6	890	2200	1480
4-Stand	11	2200	3300	3030
5-Stand	9	2500	6250	4440

Since the horsepower required for rolling is almost directly proportional to speed, a considerable concentration of power is necessary to drive such mills. Of the twenty-six mills listed, a total of 310,950 hp in main drive and reel motors has been supplied. The maximum total horsepower applied to any one mill is 17,550 for a five-stand tin plate mill with a maximum speed of 4950 fpm. The average horsepower for the 133 mill and reel motors driving these twenty-six mills is 2330. This is over twice the total horsepower applied to all stands and reel of the first tandem mill.

Simultaneous development of the rolling art, mill equipment, and the electrical drives has been necessary to utilize these speeds and powers. From the electrical drive standpoint, the problem of acceleration, deceleration, and emergency stopping, with the attendant problem of gage control during periods of changes in speed have received considerable attention, and this paper will be limited to a discussion of these characteristics. A new concept of measuring the accelerating ability of motors operated in tandem called "acceleration lag" will be suggested.

In a paper read before the association in 1938, Messrs. Læding and Rhea reached the conclusion that the WR^2 of the motors and mills should be balanced as nearly as possible, and that the resistance drops in the armature circuits of the motor should also be balanced for the best acceleration characteristics. At the time of this paper, most tandem cold reduction mill drive consisted of duplicate motors geared to the various stands and such reasoning was appropriate. Nevertheless it is practically impossible to balance both values with modern mill layouts and with motors of reasonable design. Because of the high speed and power involved, the majority of present mills are arranged for direct drive with the motor horsepower and speeds selected to meet the individual stand requirements. The per cent armature IR drop is usually higher for the low speed motors on Stand No. 1 and decreases through the mill because of the successively higher speed motors on the later stands. With modern low inertia motor designs, the per cent accelerating torque is generally higher toward the delivery end of the mill because of the increased stored energy in the mill. Refer to Table II for typical values of per cent IR drop and per cent accelerating torque. Since it is impossible to independently balance per cent IR drop and per cent accelerating torque, a term that takes both of these factors into consideration should be used.

TABLE II

MILL ACCELERATING STUDIES

Mill	Function	Stand					Reel	Width	Max fpm
		No. 1	No. 2	No. 3	No. 4	No. 5			
A	% Acc torque	26.1	36.8	41.5	61.5	.....	37.5	56	3020
	% IR drop	5.45	3.9	4.5	4.5	.....			
	% IR compensation	68.0	72.0	60.0	60.0	.....			
	% Acc lag with comp	0.45	0.40	0.75	1.11	.....			
	% Acc lag no comp	1.42	1.43	1.87	2.77	.....			
B	% Acc torque	40.7	41.9	33.1	55.8	63.5	54.2	42	4950
	% IR drop	4.56	3.18	3.5	3.55	3.31			
	% IR compensation	80	77	69	63	45			
	% Acc lag with comp	0.37	0.31	0.27	0.54	1.1			
	% Acc lag no comp	1.86	1.33	1.16	1.98	2.10			
C	% Acc torque	33.4	30.7	35.0	54.0	72.0	78.0	42	4680
	% IR drop	6.15	4.42	4.36	3.12	3.05			
	% IR compensation	0	45	41	19	15			
	% Acc lag with comp	2.06	0.75	0.9	1.35	1.87			
	% Acc lag no comp	2.06	1.36	1.53	1.68	2.20			
D	% Acc torque	62.0	29.0	43.0	47.5	.....	42.0	54	3200
	% IR Drop	3.5	4.6	3.2	3.2	.....			
	% IR compensation	0	40	22	37	.....			
	% Acc lag with comp	2.16	0.87	1.08	0.96	.....			
	% Acc lag no comp	2.16	1.34	1.38	1.52	.....			
X	% Acc torque	31.9	34.1	38.2	43	.....			
	% IR drop	3.46	3.46	3.46	3.46	.....			
	% Acc lag no comp	1.1	1.18	1.32	1.48	.....			1264
Y	% Acc torque	37.5	32.1	35.2	39.2	42.2			1485
	% IR drop	3.15	3.46	3.46	3.46	3.46			
	% Acc lag no comp	1.18	1.11	1.22	1.36	1.46			
Z	% Acc torque	29.6	55.5	61.8	77.8	.....			1500
	% IR drop	2.88	2.57	2.57	2.57	.....			
	% Acc lag no comp	0.85	1.43	1.59	2.14	.....			

Notes:
1. % Acc torque — % Torque to accelerate from 0 to 100 per cent speed in 10 seconds.
2. % Acc lag due to accelerating torque. This value will be reduced depending on the amount of IR drop compensation used.

Actually for the past number of years the accelerating merits of tandem cold reduction mill motors were judged solely on the per cent accelerating torque. The general practice has been to calculate the accelerating torque on the basis of a change of from zero to maximum rated speed in 10 seconds. Alone this value means little, except as to the commutating limits of the direct current motors involved. It is proposed that "acceleration lag" which is the "per cent IR drop due to accelerating current for a ten second acceleration" be adopted as a standard for judging the ability of a group of motors to accelerate properly. A ten second accelerating period is chosen so that the values may be easily ratioed for a different time.

As an example, consider two motors connected in parallel to a common bus. If the motors both have zero armature circuit resistance, they will stay in step as the bus voltage is changed, regardless of the value of connected inertia. An infinitesimal change in bus voltage would circulate the current necessary for acceleration and the motor speed would follow the bus voltage without lag.

For a further example, consider that the calculated per cent accelerating torque is 50 per cent on each motor, which is equivalent to 100 amperes accelerating current. (Each motor is rated 200 amp, 600 v.) If one motor has an armature resistance of 0.1 ohms, the IR drop due to accelerating current which is "acceleration lag" will be 10 volts or 1.65 per cent based on 600 volts rating. If the second motor has an armature circuit resistance of 1.0 ohm, the IR drop due to accelerating current or "acceleration lag" will be 100 volts or 16.6 per cent. The second motor will lag far behind the first as the bus voltage is raised, since the bus must get past 100 volts before the required torque can be developed. Even though the per cent accelerating currents are exactly matched, the motors would fail miserably to stay in step. This is indicated in Figure 1 which shows how motors of 1.66 and 16.6 "acceleration lag" follow a uniform 6 second change in bus voltage. Zero rolling load was assumed in calculating the curves.

If the "acceleration lag" of both motors were to be matched by changing either the WR^2, or the armature resistance drops then both motors would accelerate in step. For example, if both motors have 100 amp accelerating current and 0.1 ohm armature circuit resistance, the "acceleration lag" will be the same and both motor speeds will lag exactly the same amount behind the bus voltage change. As long as the "acceleration lag" values are the same, this will be true regardless of variation of individual resistance and accelerating current components.

A more useful method of calculating "accelerating lag" is to multiply the "per cent of full load accelerating

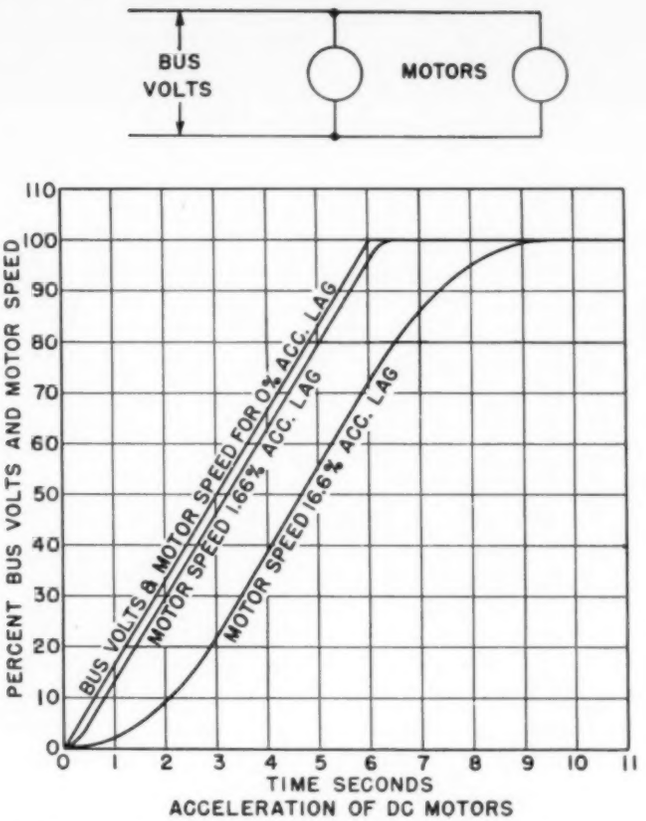
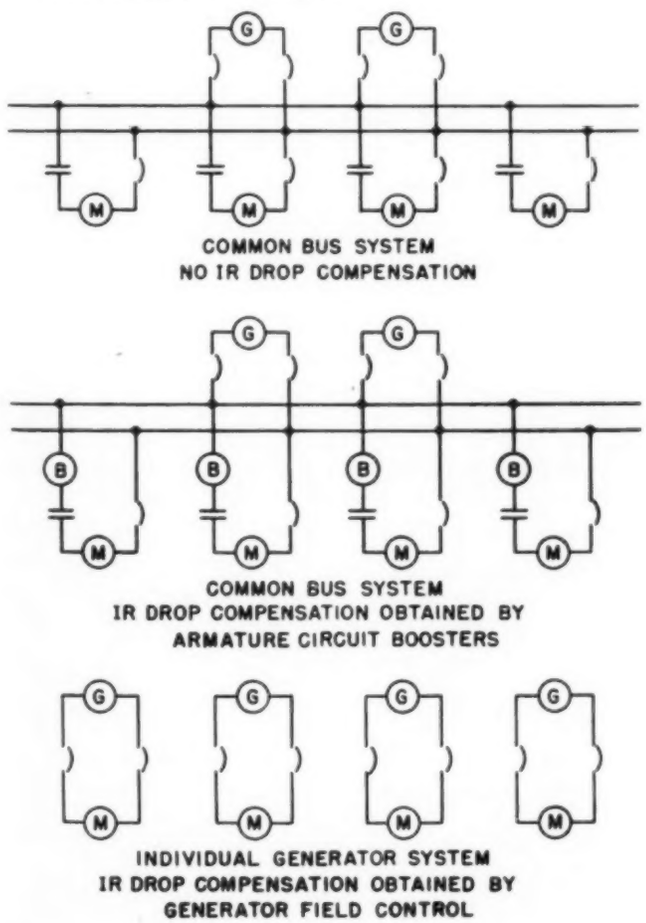

BUS VOLTS
MOTORS
PERCENT BUS VOLTS AND MOTOR SPEED
TIME SECONDS
ACCELERATION OF DC MOTORS
BUS VOLTS & MOTOR SPEED FOR 0% ACC. LAG
MOTOR SPEED 1.66% ACC. LAG
MOTOR SPEED 16.6% ACC. LAG

Figure 1 — Curve shows how the speeds of two direct current motors with different "acceleration lag" values follow a uniform change in bus voltage.

Figure 2 — Main armature circuit connections for tandem cold reduction mill drives.



torque" by the "per cent IR drop at full load current." For the example above, the per cent accelerating torque is 50 per cent. The per cent full load IR drop is $\frac{100 \times 0.1 \times 200}{600} = 3.33$ per cent. The "acceleration lag" is then $\frac{50 \times 3.33}{100} = 1.66$ per cent. This method is desirable because of the ease of taking into account the "IR drop compensation" used. It is only necessary to reduce the "per cent full load IR drop" by the amount of IR drop compensation before calculating the "acceleration lag." For example if 60 per cent IR drop compensation is used, the equivalent "per cent IR drop at full load" is (1.0 — 0.6) 3.33 = 1.33 and the "acceleration lag" is then $\frac{50 \times 1.33}{100} = 0.665$ per cent.

The "acceleration lag" represents exactly how far back of the changing voltage the motor speed will lag, since it takes into account the mechanical inertia, the accelerating current, and the motor design factors. If divided by ten, it becomes the actual mechanical time constant of the motor in seconds. Most modern mills use IR drop compensation which can easily be taken into consideration in calculating "acceleration lag" values. It is therefore the proper criterion for judging the ability of motors to stay in step during acceleration. Some of the factors affecting "acceleration lag" and the range of values for successful performance based on operating experience will be tabulated below.

Since IR drop compensation directly affects the value of acceleration lag, a review of the drive schemes in general use and the methods of obtaining IR drop compensation is in order. There are two systems in general use for the control of tandem cold reduction mills. These are shown in Figure 2 which is a schematic representation of the main armature circuits of the stand motors and power supply generators.

Until 1938, a simple common bus system without IR drop compensation was used on all tandem mills. With this system all motors and generators are connected to a common bus and the mill is accelerated by raising or lowering the bus voltage by generator field control. To adjust the individual stand drives for different rolling schedules the speed of the motors are changed by shunt field control.

In 1938 boosters were added to the common bus system as shown in Figure 2 when automatic IR drop compensation was developed. IR drop compensation offered an excellent means of improving acceleration and threading characteristics of the mill, as well as improving gage control both at top speed and during speed changes. Most of the mills since this date have been provided with IR drop compensation which is generally regarded as necessary with the higher speed mills. A few mills have been installed comparatively recently without IR drop compensation. In these cases, the stored energy and inherent IR drop values were consistent with good operating practice without resorting to the use of IR drop compensation. Therefore it was omitted.

The individual generator system as shown in the

lower part of Figure 2 was developed in 1945 and the majority of drives furnished since that time have used the system. The simplicity and flexibility of the individual generator system has been covered in previous papers and so no attempt will be made to list them here. With the common bus system, the main bus ties the stands together so that they all receive the same accelerating voltage. With the individual generator system, a control or reference bus is used and all stands are matched to it through a precise control system. IR drop compensation is obtained through generator field control thus eliminating the costly IR drop boosters.

The problem of mill acceleration is the same whether a common bus system or an individual generator system is used. Factors such as mechanical inertia, motor design, and IR drop compensation affect each type of drive in a similar manner. The individual generator system however offers automatic inertia compensation which is obtained by adjusting the amplification and the damping of the stands having the highest acceleration lag so that the generators lead slightly in voltage. The details of this will be discussed later in the paper.

Table II titled "Mill Acceleration Studies" gives data on several mills put into operation comparatively recently and three typical mills of the older type. For the newer mills, representative data is tabulated under A, B, C, and D for two four-stand and two five-stand mills. The per cent accelerating torque and the "acceleration lag" is given on the basis of maximum motor operating speed. For both the four and the five-stand mills, a common bus and an individual generator drive with successful operating records were selected.

It will be noted from the table that there is a fairly wide variation of both per cent accelerating torque and "acceleration lag." The ratio of maximum to minimum accelerating torque for the individual mills A, B, C and D varies over a range of from 1.92 to 2.36 which is not a wide difference considering the different types of mills and the different horsepowers and speeds involved. The ratio of maximum to minimum "acceleration lag" without compensation varies from 1.61 to 1.94. The most pertinent figures are the "acceleration lag" with operating values of IR drop compensation. For the individual mills, these ratios vary over a range of 2.46 to 4.07. Actually one of the mills was operated for a considerable period of time very successfully with no IR drop compensation and under this condition the ratio of "accelerating lag" throughout the mill was 1.62.

Table II gives under X, Y, and Z the data on the three mills installed around 1935 and all operated without IR drop compensation. On mill "X" the motors are duplicates, all except one are duplicates on mill "Y," and it will be noted that the acceleration lag has a very narrow range of variation. On mill "Z" the motors were selected in accordance with the horsepower required instead of making all motors duplicate rating. The ratio of lag with this mill is about the same as with the more up-to-date mills.

In actual practice, it is impossible to match the "acceleration lag" for all rolling schedules, since the motors are operated at widely different speeds, and the "accelerating lag" varies as the square of the motor speed as does the accelerating torque. This is understandable since as the motor field is strengthened to lower the speed, the available torque rises and the speed change through which the motor must be accelerated drops. For mill "A," the range in acceleration lag values from minimum to maximum rpm is given in Table III.

TABLE III

Stand	1	2	3	4
Per cent lag — Maximum rpm	1.42	1.43	1.87	2.77
Per cent lag — Minimum rpm	0.23	0.36	0.37	0.44

Actually for some schedules Stand No. 1 may be near base speed and Stand No. 4 may be near maximum speed. The range in these values is 12 to 1 which is about standard for mills of this type.

Since the acceleration lag cannot be matched for all rolling schedules, it would appear desirable to examine the limits of the absolute value of acceleration lag on those mills with good operating practice. In examining these values, bear in mind that mill "C" was operated successfully for a considerable period of time without IR drop compensation. The highest value is then 2.2 and the lowest value 0.27. The range of these values at maximum motor speed is shown in curve form on Figure 3. For comparison, the values for the mill labeled "Y" have also been plotted. If Stand No. 1 is eliminated, the trend of the compensated values from Stands No. 2 to 5 is almost uniformly upwards although the absolute values vary appreciably. Stand No. 1 for mills A and B follow the trend, but Stand No. 1 for mills C and D departs considerably. There is good reason for this because on mills C and D the No. 1 Stand is operated without compensation so it will drop in speed more than proportionally from operating speed to threading speed. This causes build-up in tension between Stands No. 1 and 2, and aids gage control as will be discussed later. In fact, most of the variations can be attributed to different operating adjustments and practices of the various mills. The curves of Figure 3 will serve as a guide in the design of new drive systems and in evaluating the performance of existing drives.

Table IV gives "acceleration lag data" for a mill to be installed soon and to which very careful study was given during the design stage in order to make the values as low as possible. It will be noted that the absolute values of "acceleration lag" are small, and the maximum possible ratio is also small, being only 5.7 to 1. This mill is 36 in. wide, has small work rolls and back-

TABLE IV

ACCELERATION STUDIES

Stand	1	2	3	4	Reel
% Acc torque, max speed	32.1	42.6	33.5	40.8	47.3
% Acc torque, min speed	5.2	7.85	8.4	10.2	.....
% IR drop	4.4	3.0	3.3	2.4	.....
% Acc lag, no comp, max speed	1.41	1.28	1.11	0.98	.....
% Acc lag, no comp, min speed	0.225	0.235	0.28	0.25	.....
% Assumed IR compensation	60	60	60	60	.....
% Acc lag with comp, max speed	0.56	0.51	0.44	0.39	.....

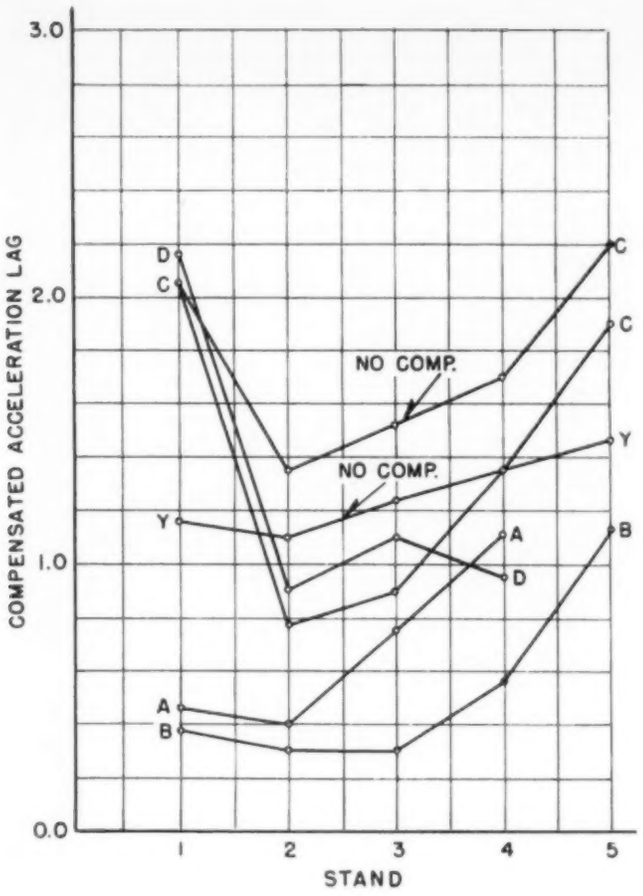


Figure 3 — Curves of operating values of compensated acceleration lag for several different mills with successful operating records.

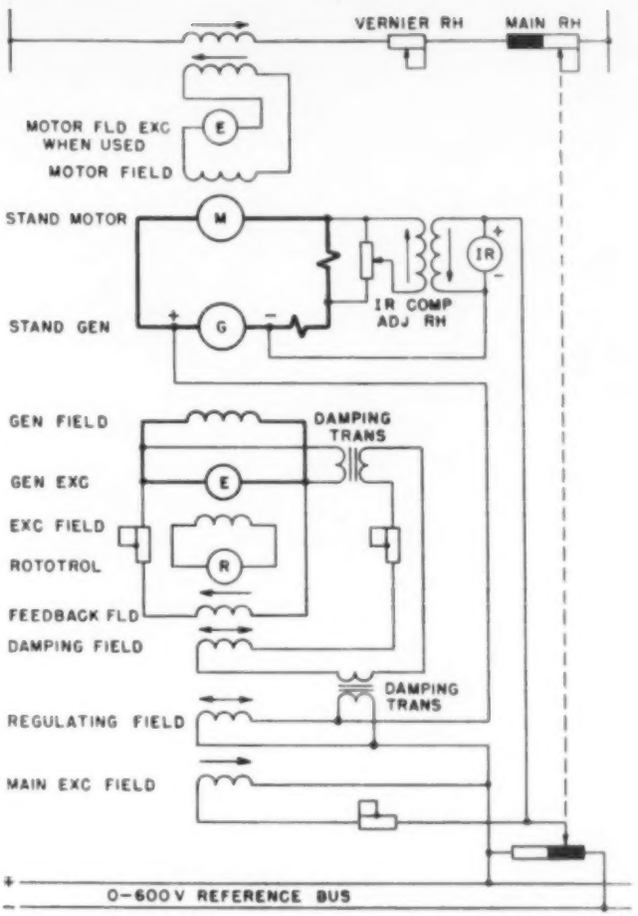


Figure 4 — Schematic diagram of control for one stand of an individual generator drive system.

up rolls and is designed for a maximum speed of 3115 fpm. Both the motor horsepower ratings, the mechanical inertia involved, and the motor speed ranges were favorable toward obtaining low values of "acceleration lag." It was hoped that this mill would go into operation before presentation of this paper, but such is not the case. The start-up of this mill will be watched with a great deal of interest since the "acceleration lag" values with IR drop compensation assumed at 60 per cent are unusually low.

No load was considered in the above analysis and the criticism might be made that the degree of rolling load affects acceleration. It does, as well as other factors such as tension between stands and the change in gage as the mill speed is changed. These factors however do not destroy the separate and distinct characteristic of "acceleration lag" nor do they make it less desirable to have as low and as well matched acceleration lags as is possible. The presence of rolling load results in an IR drop which causes the stand speed to drop a specified amount of rpm, whether the stand is at threading speed, acceleration, or at steady running speed. If all stands had the same proportion of load and the same resistance drop, then these factors would cancel out entirely. In practice they tend to compensate for one another but will not cancel out, particularly on the No. 1 Stand which is usually very lightly loaded. Tension between stands equalizes any difference which exists in acceleration parameters. A change in tension causes an interchange of energy between stands as well as affecting the reduction, both of which compensate for the change. As the mill is decelerated, the gage becomes heavy which on a well adjusted mill will cause an increase in tension between all stands. If the tension meters are observed on such a mill, it is remarkable how smoothly they change from operating to heavier tensions as the mill is decelerated and from the heavier tension to operating tensions as the mill is accelerated. This of course is to be expected if the acceleration lags are relatively low and are as well matched as possible.

With the individual generator system, compensation can be made for differences in "acceleration lag" factors. Figure 4 is a schematic representation of the control system for a one stand of such a system. All stands are matched to the same reference, and the mill is accelerated or decelerated by raising or lowering the reference bus voltage. Any difference between this voltage and the stand generator voltage circulates a corrective current through the regulating field. This control system has the necessary damping, feed back, and main excitation fields to assure the following features:

a. High amplification and thus high accuracy to provide the proper tracking of all stands from threading to maximum speeds.
b. Very fast and well damped transcient response.
c. No overshoot under any operating condition.
d. Simplicity of scheme and adjustments for IR drop compensation, amplification and damping.

The oscillogram of Figure 5 shows the transient response for a typical stand at weak field or maximum

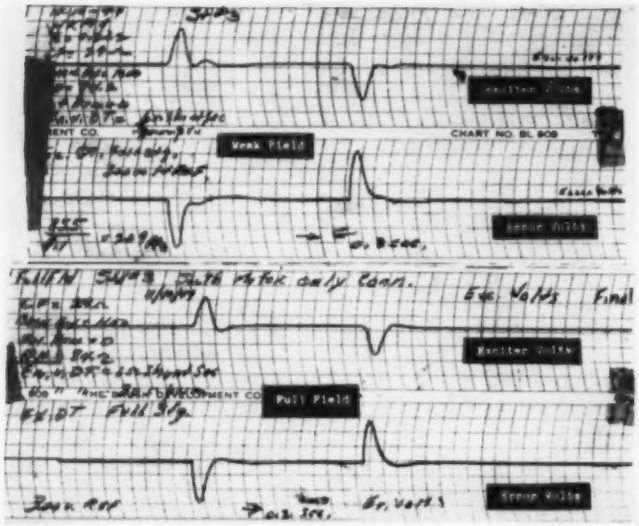


Figure 5 — Response of a 3000-hp stand drive system to a sudden change in reference bus voltage.

speed, and full field or minimum speed. This test was made by inserting an instantaneous voltage into the rotating regulator regulating field which is a more stringent test than any mill operating condition. It however serves as an excellent measure of control system performance. The oscillogram trace labeled Error Volts indicates that the correction is made very quickly and with a negligible overshoot. The oscillogram also shows the exciter voltage during the disturbance which reaches a peak of 250 per cent of that normally required to maintain the generator voltage. This tremendous forcing for a small change in regulated function is responsible for the fast system response.

Figure 6 is an oscillogram of the stand voltage as compared to changes in reference bus voltage for seven second acceleration and deceleration. A comparison of the two traces shows that the generator voltage follows the reference bus very closely and that at no point is there any overshoot.

It is important that the responses of all stands be essentially the same in order to assure balanced mill performance for all rolling schedules. Table V shows the response for all five stands of a typical mill at weak motor field or maximum speed, and full motor field or minimum speed. The response time for full correction at weak field is longer than at full field, but it will be noted that the time for 80 per cent correction at weak field is practically the same as for full correction at full field. Thus regardless of the motor field strength for different rolling schedules, the response of all stands is fast and essentially uniform. The importance of this factor when a variety of different rolling schedules must be met cannot be overemphasized.

With a fast and stable individual generator control system, the amplification and damping of the individual stands can be adjusted to compensate for differences in "acceleration lag" of adjacent stands. Figure 7 shows oscillograms of difference voltages between adjacent stands on a five-stand mill which has been adjusted in this manner. In this case, the voltage of the generator for the higher numbered stand of each pair has been adjusted to lead in voltage. Since the acceleration lag of Stand No. 5 is 2.2 and that of Stand No. 4 is 1.68, the adjustment to force the voltage of generator No. 5 to lead that of generator No. 4 practically compensates for this difference.

For Stands No. 3 and No. 4, the acceleration lag of 1.53 and 1.68 respectively are practically the same, and so the systems were adjusted for essentially no difference. It will be noted that the voltage difference between these two stands is approximately one volt out of 600.

The acceleration lag of Stand No. 2 is 1.36 as compared to 1.53 for Stand No. 3, and the adjustment of Stand No. 3 generator was such that it leads Stand No. 2 on acceleration and deceleration. Although the acceleration lag of Stand No. 1 is 1.68 which is greater than that of Stand No. 2, the voltage of generator No. 2 is adjusted to lead that of generator No. 1 for gage control reasons.

Such adjustment results in automatic inertia compensation and is beneficial in that the relations between stands more nearly approach normal rolling operations during changes in speed. Because of the difference in "acceleration lag" factors for different rolling schedules as indicated by Tables III and IV, care must be exercised to not adjust too far in this direction.

It is imperative that a control system so sensitive and so fast in response "stay put" once it is adjusted. Otherwise the adjustments discussed above mean

TABLE V

RESPONSE OF STAND CONTROL SYSTEMS

Stand	Weak motor field response-seconds full correction	Weak motor field response-seconds 80 per cent correction	Full motor field response-seconds full correction
1	0.65	0.42	0.40
2	0.67	0.40	0.42
3	0.65	0.30	0.35
4	0.70	0.38	0.35
5	0.60	0.39	0.40

Figure 6 — Oscillogram shows how the stand voltage follows the reference bus for a 7-second acceleration and deceleration.

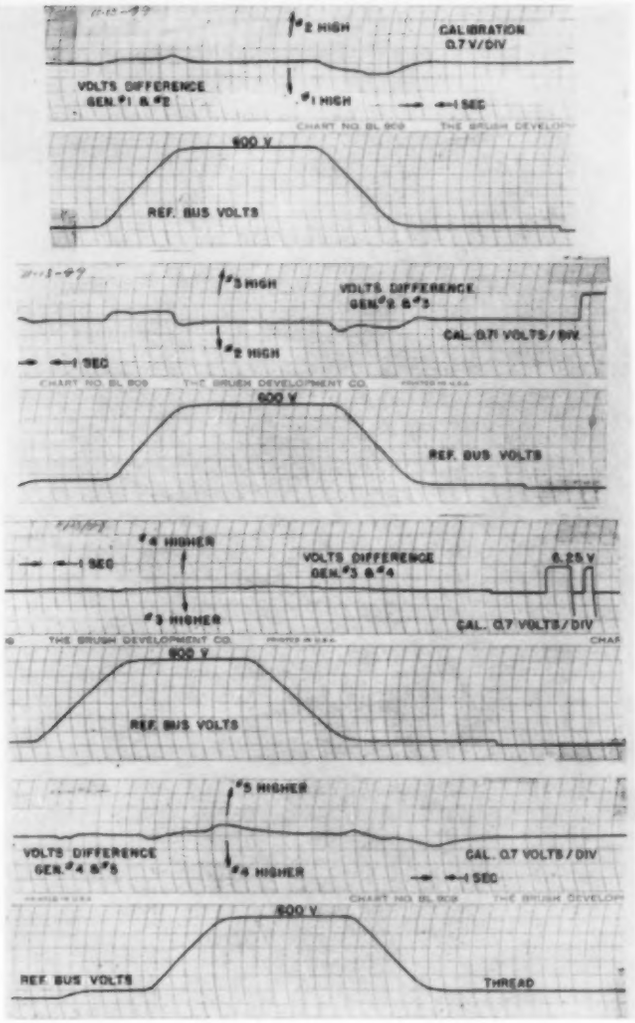


Figure 7 — Oscillograms show voltage differences between adjacent stands of a 5-stand, 4680-fpm mill for a 6-second acceleration and deceleration.

nothing and the mill operation will suffer. The excellence of the system described is demonstrated by the following data. During the first week of December 1949, a five-stand tinplate mill with a maximum speed of 4680 fpm was put into service. The stand controls had been previously tested and adjusted, mostly with the spindles disconnected. A short check test was made with the mill connected and screw pressure but no metal. The first coil was rolled with these adjustments, and the mill went into production with no changes on the stand controls. About six months later the mill people noticed from observation of the meters that the regulating field current on one stand was not as near zero as were the others. The main excitation field for this stand was adjusted to make the regulating field current essentially zero at operating speed. No other adjustments have been made except for changes in IR drop compensation to improve gage control. A duplicate mill was put into operation in April 1950 after being similarly adjusted. To date no changes have been made on the stand controls and none are contemplated.

So that mill damage during emergencies will be minimized, a smooth rapid emergency stop made at a maximum rate consistent with the commutating capacity of the stand motors is an essential requirement of all tandem cold reduction mill drives. Here both the per cent accelerating current and the "acceleration lag" are important. The per cent accelerating current determines how fast the stop can be made without exceeding the commutating limits of the motors. The "acceleration lag" values determine how successfully the stop will be made. The emergency stop system should provide the following features:

1. The stop should be initiated in the shortest possible time which results in less strip being paid out at high speed, and less possibility of roll damage when a break occurs.
2. The mill should be stopped in the shortest possible time consistent with the motor field setting to take advantage of the lower accelerating current and lag at stronger motor fields.

Figure 8 shows the stopping of the No. 5 stand motor of a five-stand mill operating at 4680 fpm unloaded. At lower speeds the stop is made proportionally faster. This curve has been plotted from an oscillogram, and zero time represents the instant the emergency stop button was depressed. The curve shows that the motor speed starts down in 0.3 seconds which is not much above the "acceleration lag" of this stand drive indicating that the reference bus and applied motor voltage starts down almost instantaneously. During 90 per cent of the stop, the rate of deceleration is essentially constant and tapers off to give a very smooth stop without "rocking" or "creeping." The current during the greater part of this stop was slightly above 200 per cent of rated value. Recently the authors observed a reel break on this mill which required an emergency stop from 3500 fpm. The mill came to a stop rapidly and smoothly with no additional breaks, and maintained tension between stands after the mill came to rest. Table VI gives the observed operating tensions between stands as well as the tensions with the mill at rest after this emergency stop.

The performance of the reel drive is also an important part of an acceleration study. The problem is different

Figure 8 — Emergency stop plotted from an oscillogram for the speed of the fifth stand of a 4680-fpm mill.

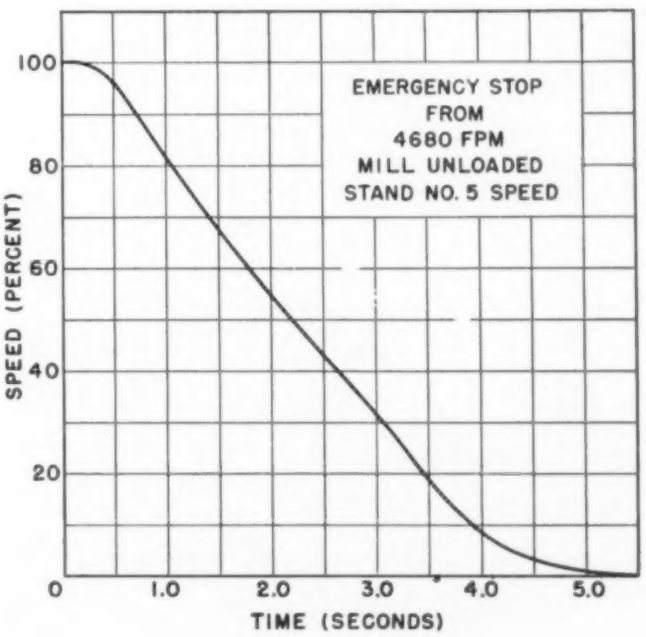


TABLE VI

Tensiometer Location	Operating tension, lb	Mill at rest, tension, lb
4-5	10,000	24,000
3-4	19,000	20,000
2-3	33,000	35,000
2-1	55,000	38,000

from that of the stand controls because the current of the reel is regulated to maintain tension. During changes in mill speed, this current must be changed to compensate for the reel inertia so that essentially constant tension is maintained. It is important that the inertia compensation be applied and removed at the correct times in order to prevent either excess tension or slack in the strip.

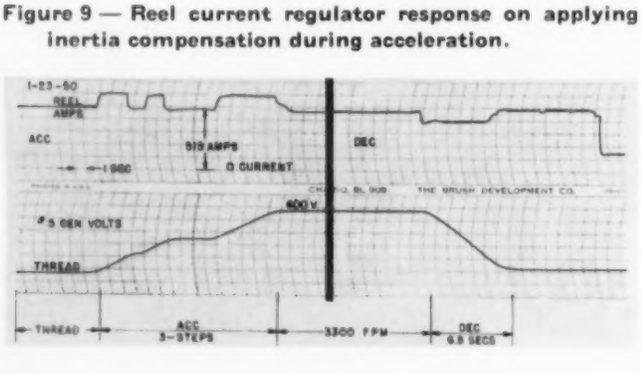
Figure 9 is a chart of reel motor current and Stand No. 5 generator volts taken on a five-stand mill for one coil. For this test the mill was purposely accelerated in several steps but decelerated in one step. An examination of the chart shows that the control rapidly forces the reel motor current to the correct accelerating value during each step of the acceleration and returns it to the steady rolling value when a given step of acceleration is completed. The time required to change the current from one value to another is approximately 0.2 seconds and this is accomplished with negligible overshoot.

The middle of the chart has been removed since this represents the steady rolling period and it is of interest, only to indicate that the control maintains the same current for the complete coil. On deceleration the control functions to reduce the current to hold proper tension. This is accomplished as rapidly and as smoothly as on acceleration.

The demand for closer tolerances on gage, and the importance of off-gage material to the cost of producing a specified amount of saleable strip, have resulted in considerable interest in gage control.

Corrections in gage at operating speeds are easily obtained by screw adjustment or by changing motor speed to adjust the tension between stands. A "tight" mill — heavily IR compensated — will give more uniform gage without adjustment by the operator than will a "soft" or lightly IR compensated mill. With a "tight" mill, variations in incoming gage or hardness cause variations in tension which change the reductions to compensate for the variation. Local mill conditions such as type of lubricant and coolant used, as well as

Figure 9 — Reel current regulator response on applying inertia compensation during acceleration.



the character of the steel, determine the operating practice with regard to a "tight" or a "soft" mill. Table VII shows the operating adjustments for several

TABLE VII

VARIOUS MILL OPERATING ADJUSTMENTS

PER CENT NO-LOAD TO FULL-LOAD REGULATION

Stand	Mill A	Mill B	Mill C	Mill D	Mill E	Mill F	Mill G	Mill H
1	1.70	1.90	6.2	3.5	5.0	2.0	5.20	3.00
2	1.10	1.30	2.4	3.0	4.0	1.7	4.90	3.60
3	1.80	1.40	2.6	2.5	3.0	1.2	3.50	2.90
4	1.80	1.40	2.6	2.0	2.8	1.2	3.00	3.10
5	.....	1.30	2.6	.....	2.0	1.2	.....	2.40
Strip Lubricant	Palm oil	Palm oil	Solution	Solution	Palm oil	Palm oil	Solution	Solution

successful mills. The values in the table are the resultant no-load to full-load regulation characteristics with operating values of IR drop compensation. For example, a motor with 6 per cent IR drop and 60 per cent compensation would have a resultant regulation of 2.4 per cent, whereas a 3 per cent IR drop motor with the same compensation would have only 1.2 per cent regulation.

Operating adjustments of successful mills vary widely as can be seen from Table VII. This emphasizes the importance of a flexible and easily adjustable control system so that the drives will be adaptable to a wide range of local mill conditions.

If a tandem cold reduction mill could be operated continuously at normal running speed, gage control would be a relatively simple matter. However, the mill must be accelerated at the start of the coil, decelerated at the end of the coil, and at times the speed must be reduced to allow welds to pass through the mill. If a mill is set up to be on gage at operating speed and if the screw settings, cooling solution, lubricant, etc., are left fixed, the gage will become heavy when the mill is decelerated to a lower speed. For example, various tests on tandem tinplate mills have shown that the gage at threading speed may be heavy by 20 to 45 per cent.

Both the accelerating characteristics of the drive and the steady running operating adjustments are important factors affecting the point the mill gets on gage during acceleration. In general IR drop compensation makes it possible to get on gage sooner when the mill is accelerated, and to stay on gage longer as the mill is decelerated. Both the amount and the distribution of IR drop compensation are important. Since the gage naturally gets heavier at the low speeds, and since IR drop compensation tends to make the motor speeds remain more nearly proportional under threading speed conditions, a greater than normal increase in tension occurs from running speed to threading speed. The tendency is to keep the metal more nearly on gage at the lower speeds because the metal is reduced by combination of roll pressure and tension.

It is desirable to arrange the compensation values so that the tensions build up as much as possible between the earlier stands. This has the effect of pulling the metal more nearly on gage where it is softer and heavier

and can better withstand higher tension. This practice also has the very desirable feature of reducing the tension build-up between Stands No. 4 and 5. The amount of tension that can be used is limited by the character of the steel as the presence of bad edges, holes in the strip or other weaknesses may result in breaks at the higher tensions.

The relative values of acceleration lag are also important to getting on gage during the accelerating period. A poor layout of acceleration lag factors either due to design or adjustment would make it difficult for the mill to get on gage until operating speed were reached. Since it is not possible to match "acceleration lags" for all rolling schedules, the values should be as low as practical. The use of IR drop compensation with all drive designs and the addition of compensation for lag with the individual generator system are both means of reducing acceleration lag values. With low lag values, the motor speeds will stay more nearly in the correct proportion during acceleration and deceleration. Thus the various stand drives will have close to the same performance during acceleration and deceleration as they have during normal rolling operations.

Curves of "acceleration lag" shown in Figure 3 are typical of well balanced mill drives. The "acceleration lag" of Stand No. 1 is slightly larger than that of Stand No. 2 for all but two mills for which it is much larger. With this adjustment on these two mills, the tension between Stands No. 1 and No. 2 increases on acceleration which results in pulling on gage more quickly. To obtain the same result, the voltage of Stand No. 2 is adjusted to lead that of Stand No. 1 even though the "acceleration lag" of Stand No. 1 is the greater of the two.

Modern mills with the best operating practice get on gage at 40 to 60 per cent speed on acceleration, and do not get off gage until the metal leaves the No. 1 stand on deceleration. Mill C in the above tables was operated for a time with essentially no IR drop compensation and the tendency was to come on gage at a little above 80 per cent speed during acceleration. With the operating values of IR compensation as shown, the mill generally comes on gage at slightly above 200 volts which is some 34 to 40 per cent speed. Observation of the mill when rolling 0.080 to 0.0109 in. at 3100 fpm, showed that the strip came on gage at 1200 fpm consistently, and did not get off gage until the tail was out of the No. 1 stand. A duplicate mill in the same plant with essentially the same adjustments when rolling 0.080 to 0.0087 in. strip at 3500 fpm came on gage at 1900 fpm during acceleration.

A simple example will show the importance of getting on gage quickly during acceleration. Assume a mill with an operating speed of 3000 fpm and a ten second acceleration period. If the mill does not get onto gage until top speed, 250 feet of strip will be off-gage. If the mill comes on gage at 50 per cent speed only 62.5 feet of strip will be off-gage which is a 75 per cent reduction in off-gage material during acceleration. It can also be demonstrated that faster acceleration will reduce off-gage. However, the mills do not take advantage of the fastest rates of speed change provided by the drives. Most mills 3000 fpm in speed and above use about 8 to 12 second accelerating periods and 5 to 7 second decelerating periods. The mill crews do not like faster rates because of the difficulty of making corrections during an acceleration after changing orders and in correcting shape when starting with a cold mill.

Tapered tension by motor shunt field control or by biasing the control circuits of individual generator drives has found some use as a means of gage control at speeds below operating values. It is not used to any great extent on modern drives. The use of IR drop compensation is preferred where the drive must meet a wide range of rolling schedules or where different mill set-ups are used for the same schedule. There is good reason for this. IR drop compensation is more nearly automatic and therefore more suitable for different operating conditions without adjustment.

From the data presented in this paper the following conclusions have been reached:

1. The factor "acceleration lag" in place of acceleration torque should be used to determine the ability of motors to accelerate in step.
2. Since "acceleration lag" cannot be matched for all rolling schedules, it is essential that the values be low.
3. IR drop compensation can be used effectively to reduce "acceleration lag" values.
4. On individual generator type systems, control adjustments can be made to compensate for variation in "acceleration lag" between stands.
5. The use of IR drop compensation results in more uniform gage at operating speeds.
6. With the proper values of acceleration lag and IR drop compensation, the best operating mills get on gage at from 40 to 60 per cent speed on acceleration and do not get off gage until the tail is out of the No. 1 stand.

On high speed tandem mills the importance of the accelerating characteristics of the stand drive systems cannot be overemphasized. It would be beneficial to the Association of Iron and Steel Engineers to have additional data on this type presented as further operating data is obtained.

APPENDIX I

The acceleration of a direct current motor at no-load with a uniform change in bus voltage is calculated as follows:

WR^2 = Total for motor and connected load.
g = Gravitation constant.
b = Motor torque per ampere.
i = Motor armature current.
R = Motor armature resistance.
e = Applied voltage.
a = Volts per rpm.
n = Motor rpm.

For a voltage $e = kt$ from 0 to t_1

$$\frac{2\pi}{60}\frac{WR^2}{g}\frac{dn}{dt} = bi$$

$$i = \frac{e - an}{R}$$

$$\frac{2\pi}{60}\frac{WR^2}{gb}\frac{dn}{dt} = \frac{e - an}{R}$$

$$\frac{2\pi}{60}\frac{WR^2R}{g\ a\ b}\frac{dn}{dt}+n=\frac{e}{a}=\frac{k}{a}t$$

$$\text{Let } \frac{2\pi}{60}\frac{WR^2}{g}\frac{R}{ab}=T_o$$

Motor speed from 0 to time "t_1"

$$n=\frac{k}{a}\left(t-T_o+T_o\,e^{-t/To}\right)$$

This formula is used to calculate motor speed during the period of changing bus voltage.

If after "t_1" $e=K$, a constant, the motor speed can be calculated from the following formula:

$$n=\frac{K}{a}-\frac{k}{a}T_o\,e^{-\frac{t}{To}}$$

To calculate the constant T_o

$$T_o=\frac{2\pi}{60}\frac{WR^2}{g}\frac{R}{ab}$$

$$T_o=\frac{2\pi}{60}\frac{WR^2}{g}\times\frac{R}{\frac{V}{N}}\cdot\frac{T_{FL}}{I_{FL}}$$

$$T_o=\frac{2\pi}{60}\frac{WR^2}{g}N\frac{1}{T_{FL}}\frac{RI_{FL}}{V}$$

Since the torque to accelerate in 10 seconds is:

$$T_\alpha=\frac{2\pi}{60}\times\frac{WR^2}{g}\frac{N}{10}$$

Then

$$T_o=10\times\frac{T_\alpha}{T_{FL}}\times\frac{RI_{FL}}{V}$$

If the product of per cent accelerating torque for 10 seconds and per cent IR drop has been expressed in per cent to give per cent lag.

$$T_o=\frac{1}{10}\text{ per cent accelerating lag.}$$

APPENDIX II — CALCULATION OF ACCELERATION LAG FROM MOTOR RATINGS

HP = Rated motor horsepower.
RPM = Motor speed.
T_α = 10 second acceleration torque.
T_{FL} = Full load motor torque at given motor speed.
I = Rated armature current.
V = Rated voltage.
R = Motor armature circuit resistance.

$$T_\alpha=\frac{WR^2\times RPM}{308\times 10}$$

$$T_{FL}=\frac{HP\times 5250}{RPM}$$

$$\text{Per cent accelerating torque}=\frac{WR^2\,(RPM)^2}{HP\times 16.2\times 10^6}\ (100)$$

$$\text{Per cent IR drop}=\frac{IR}{V}\times 100$$

$$\text{Per cent accelerating lag}=\frac{WR^2\,(RPM)^2}{HP\times 16.2\times 10^6}\left(\frac{IR}{V}\right)100$$

$$\text{Per cent accelerating lag}=\frac{WR^2\,(RPM)^2\times IR}{HP\times V\times 162{,}000}$$

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N. S. Walker: We have two of these mills in our plant and we never have experienced very much difficulty in accelerating and decelerating the mills, but we did have some difficulty in what the operators call "threading the mill" or "sticking the mill."

We have done quite a bit of experimenting lately in trying to get better "sticking" or threading" in these mills and we made one change that I think, helped in this a great deal. When we first started these mills, we had about 40 per cent range of speed on No. 5 Stand motor from the vernier rheostat and you could thread the mill all right, but there was a tendency on the part of the operator in using this wide range rheostat to turn it all the way back when "sticking the mill," and he would not get it back into operating position until after the mill was up to top speed. Therefore a quantity of material was rolled off-gage.

What we did was this: We cut the vernier rheostat down from approximately 40 per cent of the total speed range of the No. 5 Stand motor to 10 per cent range of the motor, and we put in about 20 per cent extra droop in the No. 5 Stand motor at "threading speed only." This made a very good sticking mill, and also consider-

ably reduced the strip breakage between No. 4 and No. 5 Stands at threading speed.

The above arrangement on No. 5 Stand motor has another advantage in that it leaves No. 5 Stand mill set satisfactorily. It is set so it will come into gage as it goes into top speed and as a result your off-gage material is reduced in quantity substantially.

T. B. Montgomery: At the time, and for some years following the paper in 1928 by Messrs. Leding and Rhea, referred to by the authors, operators of tandem mills considered the motors as simply operating from a common supply and driving a load mechanically in parallel. Therefore, old principles of parallel operation were applied and it was thought, as the authors point out, that equalization of WK^2 and IR drop values satisfied the equations of the problem.

It was a rough answer and did a job. As more questions are asked about any problem, more variables are introduced into the equation and its solution is more difficult. As problems of holding gage and increased speeds, etc., were projected, necessary characteristics of the apparatus for powering and control of the mill changed, and more questions were asked and more variables were introduced.

Rotating amplifiers of the feed-back type appeared on the scene for control and it was recognized that material advantage could be had from the use of individual generators for each motor operating mechanically in parallel on the common load, the strip. The big question was whether such separate units could be adequately controlled.

The first such mill to be ordered with individual generators was a 4-stand mill. Due to circumstances a 5-stand mill was started up before this first one went into operation. Other mills using the single generator connection were ordered and very valuable operating data is given in this paper on, among others, two 5-stand mills built by the same mill builder as the first two mentioned above.

I would like to make some comments on the first mill mentioned. While the scheme was set up in the factory in miniature and tried out, we feel that we were fortunate that the constants of the motors, generators and mill parts were such that the initial layout enabled adequate control from the start.

Ten days were allotted for adjustments and at the end of this time the rolling of steel was started and the system is operating in all essentials as it was then. With this should be mentioned the fact that the products rolled differed largely from those originally contemplated, which adds variables to the original problem. From this experience and also that on applications in other than the steel industry, it has been found that not only the steady state characteristics of the machinery, under rolling conditions but the transient characteristics, the transfer functions, and responses must be measured and must be known so that the operation under acceleration, deceleration, load fluctuations can be precalculated to avoid possibility of serious difficulty.

The term "acceleration lag" which the authors have offered as a "yard stick" for judging the ability of a group of motors to accelerate properly together is interesting. It will be valuable in stating one parameter of the problem. However, it is only one factor in obtaining a stable regulating system. It is recognized that today's high speeds and accuracy of control of the process has been made possible in large part by more accurate, precise and dependable control components. The acceleration lag is a measure of how much duty is imposed on the regulating system.

As more study is put on determining the various other parameters, namely the transient ones, the possibility of regulating system will be better known.

It is evident, to all of us, I believe, that considerable work and study has gone into this paper and the experience behind it.

It appears that the analogue computer or a simplified version of it will become a necessary tool on high speed mills as the a-c calculating board now is to transmission and distribution problems on power systems.

W. R. Harris: No one has taken issue with the analysis of the acceleration characteristics of tandem cold reduction mills as presented in the paper. Mr. Walker emphasized the importance of drive adjustment in "threading" or "sticking" the mill and the difference between wide and narrow range vernier speed rheostats. If you were to watch his mills, on both "sticking" and acceleration, you would agree that the performance is excellent. It is the result of careful drive layout and adjustment so that the mill crew can forget about the drive and concentrate on rolling steel.

Mr. Montgomery has reiterated the importance of the transient response of drive systems to present day high speed rolling and processing machinery. The tandem cold reduction mill is a classic example of a mill which must have high speed to meet production requirements, and which must have fast and well matched transient response characteristics to meet acceleration and gage criteria. Proper understanding and use of "acceleration lag" data matched with good control performance will result in a drive system which easily meets the requirements of the modern mill.

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ASSOCIATION OF IRON AND STEEL ENGINEERS, 1010 EMPIRE BLDG., PITTSBURGH 22, PA.

MOTOR INSPECTOR TRAINING

By GEORGE M. KENNEDY
Coordinator of Apprenticeship*
and On-the-Job Training
Carnegie-Illinois Steel Corp.
Pittsburgh, Pa.

. . . . inspection training for maintenance men must be practical, specific, well planned and aimed at the particular job which a man is doing . . . .

▲ THIS discussion covers some of our plans for training men for assigned maintenance jobs. In order to talk in more specific terms, the paper will describe the training of motor inspectors. This example should serve our purpose for the points of concern in these areas are typical of those found in other assigned maintenance jobs.

There are two matters of concern: first, the steps necessary to improve the performance of the present group of motor inspectors; second, the matter of providing opportunity for the helpers to acquire the knowledge needed for their self-improvement.

We have not found any new or startling solution to these problems. We are simply applying the same training principles that have proved valuable in improving the performance of men in countless other positions and in providing opportunity for interested persons to develop themselves for higher rated positions. These principles are the same ones that each of you has used effectively in the past.

The first step in planning the training of any individual or group is to gain a thorough knowledge of the job they are expected to do. So let us take a look at a typical position description for motor inspectors in Carnegie-Illinois plants. The primary function of the motor inspector is to inspect, repair, replace, install, and adjust all electrical equipment in his assigned area. The electrical equipment he services includes such items as motors, generators, controls, switches, circuit breakers, and control panels. In recent years, the problem of servicing such equipment has grown more difficult because of the rapid technical advancement in steelmaking equipment. As one example, the introduction of higher speed hot and cold strip mills has brought about complex control problems involving electronic applications.

The motor inspector reports to a foreman, but because the equipment he services is scattered over a wide area, he must work with a minimum of direction. Therefore, the calibre of the service he performs depends mainly upon his mastery of all phases of his job.

Now that we have reviewed briefly the description of this job, let us consider first the problem of how to improve the performance of the present group of motor inspectors.

One approach to solving this problem could be to train all motor inspectors in all details of their jobs. However, to do this would require considerable time and effort and we would be ignoring the fact that they already know how to perform a good part of their jobs. This must be so, for otherwise, they could not be doing the work they are doing today. To give the entire group complete training in their jobs would be a waste of their time and ours. In addition, the experienced motor inspectors would undoubtedly have little interest in training that deals with parts of their jobs they are now performing efficiently; such a step could stir up resentment rather than interest.

It is only logical, then, to take an individual approach to improving the performance of present motor inspectors. This can be accomplished by training them only in those parts of the job where they are weak. However, to do this, we need a means to reveal weaknesses of each motor inspector. That means is the comparison of their performance against the requirements of their jobs.

The detailed job requirements for motor inspectors assigned to different areas may vary because of differences in equipment they service. To make an appraisal of any individual's performance, the supervisor needs first to make a simple listing of all the things the man is expected to do to fulfill the requirements of his job, as set forth in his position description. By comparing the man's performance with the list of requirements, the supervisor can judge whether he can handle each job detail satisfactorily or whether the performance of

*At time of paper presentation.

any part requires improvement. The man's job, then, provides a factual basis to measure the effectiveness of his performance and for determining his individual training needs.

Another source of information about weaknesses in motor inspector performance is found in a study of mill delays and shutdowns due to failure of electrical equipment. This study will reveal the quality of repair work being performed, as well as the time spent on such work. This information may not provide facts about any one motor inspector's performance but it does give valuable clues to appraising the over-all efficiency of the entire group of motor inspectors employed in the area. Further, such a study provides clues to any weaknesses that are common to the group and are, therefore, indications of group training needs.

By comparing men's performance with the requirements of their jobs and by studying reports of mill delays, the supervisor can get most of the facts needed to judge his motor inspectors' strengths and weaknesses. There may be a few cases where he has some doubts about an individual's ability to a certain task. In these cases, the supervisor can determine the facts by giving the man a performance assignment. Job performance assignments are typical field jobs that are assigned to workmen to find out whether they can satisfactorily perform the tasks in question. The individual getting the assignment is given all necessary details as to what is to be done, when the task should be completed, and the prints or sketches and equipment required. When the assignment is completed, the supervisor checks the work performed to see whether it meets the quantity, quality, accuracy, and time requirements. When this step is completed, all of the facts concerning individual performance should be known.

Once the supervisor has a complete and factual picture of each motor inspector's weaknesses, he is ready to develop the specific training plans to improve each man's performance. He begins by pinning down the knowledge and skill each individual must acquire in order to perform those tasks which are causing difficulty. By reviewing each of these tasks step by step, the supervisor can determine what the man needs to know about such matters as electrical theory, mathematics, wiring diagrams, or the design and operation of a particular piece of equipment. He can also determine the job skills required to perform these tasks.

Knowing the specific training needs of his motor inspectors, the supervisor next selects the training methods to be followed. The methods usually employed are based on either job instruction or classroom instruction, depending upon the subject to be put across.

Job instruction methods are used to teach the job knowledge and skills required. These include such matters as specific duties, local rules and procedures, the location of equipment and controls, and practical methods of testing electrical circuits and of locating troubles. When possible, the individual receives job instruction on-the-job under his supervisor's direction. Here, the man being trained can apply his new knowledge and skill directly in servicing the equipment for which he is responsible.

However, job instruction on-the-job is not always a practical approach to some phases of the motor inspector training problem. These phases of the problem center

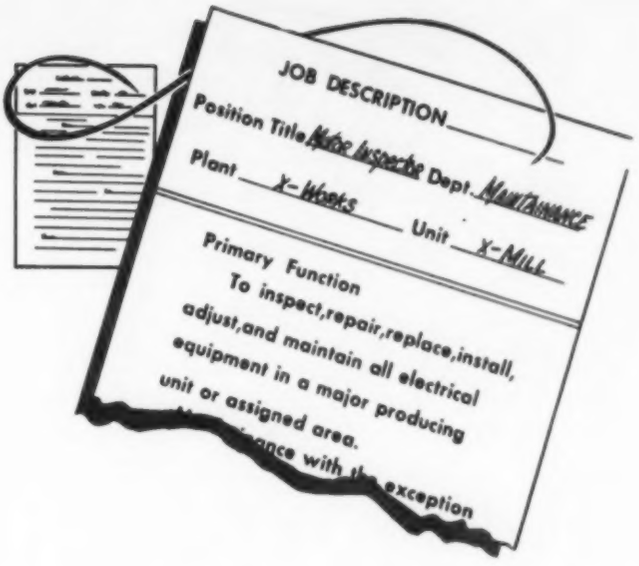

JOB DESCRIPTION
Position Title Motor Inspector Dept. Maintenance
Plant X-Mills Unit X-Mill
Primary Function
To inspect, repair, replace, install, adjust, and maintain all electrical equipment in a major producing unit or assigned area.
exception

Figure 1 — Setting up a complete job description is an essential initial step in training the person.

Figure 2 — The second step in setting up a training program is to analyze the capabilities of existing personnel.

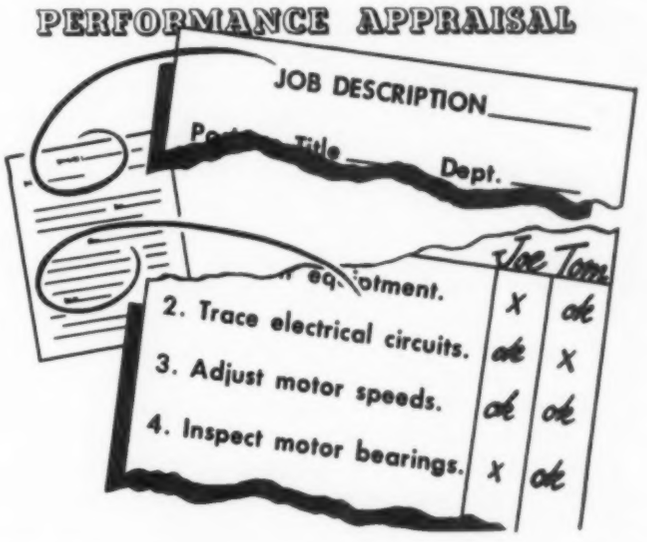
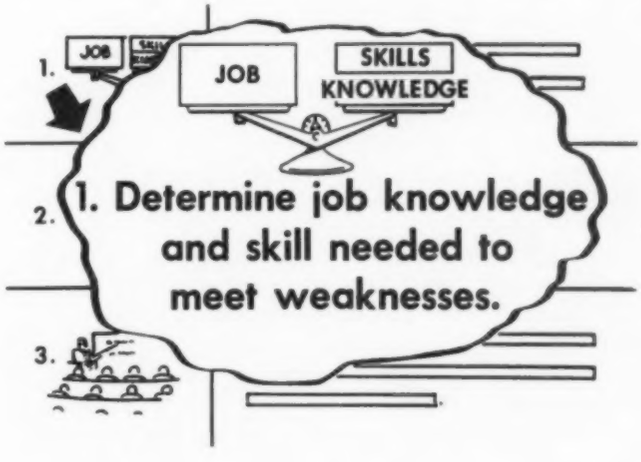


Figure 3 — It is essential to develop specific training plans.



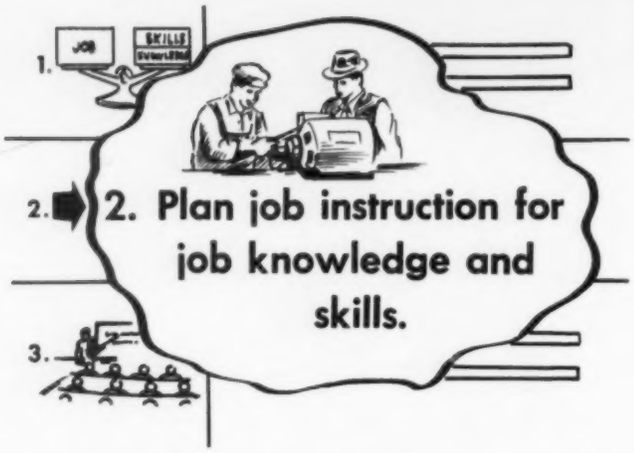


Figure 4 — Instruction should be so planned as to give the man the skills that he needs for the particular job and equipment he is maintaining.

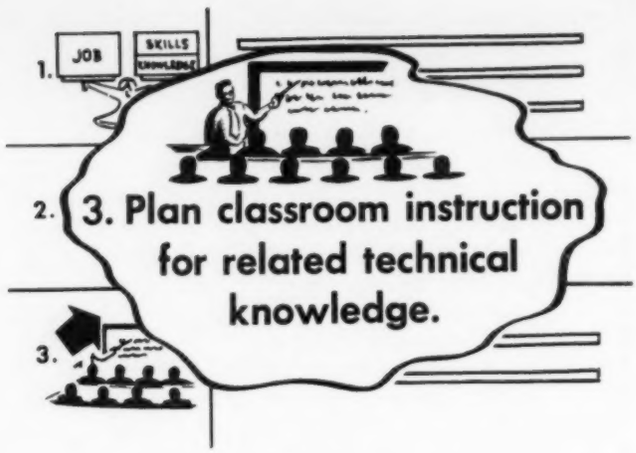


Figure 5 — Classroom instruction is an important auxiliary to on-the-job training.

around locating equipment troubles and failures, and making necessary repairs or adjustments. While it would be ideal to train motor inspectors in these subjects at the times the troubles or failure occur, this is not always possible because during such emergencies there is not sufficient time for adequate training. The defective equipment must be repaired or replaced, and operations resumed with as little delay as possible. For this reason, job instruction is frequently given off-the-job. To do this, we find a convenient spot in the electric repair shop or a nearby building and set up equipment similar to that in use in the operations. The equipment used for training purposes can be stopped, started, or altered to simulate the troubles encountered in the actual job situation. Here, motor inspectors can be taught how to make inspections, locate troubles and repair or replace equipment — all without any interruptions or delays to operations. At these training locations, we can give job instruction to men individually or in small groups. When many persons need the same instruction, this means of training them on a group basis is a real time saver.

In addition, these facilities that are set up for training purposes can be used to give motor inspectors the kind of performance assignments previously mentioned. Here, again, this equipment can be adjusted or altered to set up the kind of troubles met out on the job. When the supervisor has any doubts about a man's ability to perform a certain task, he can check his ability directly by this means.

The method of job instruction we have discussed so far does not meet all of the training needs of motor inspectors. They also need the technical knowledge related to their jobs which includes subjects like electrical trade theory, wiring print and symbol reading, mathematics and the principles of mechanics. These related technical subjects are usually handled by classroom instruction under the direction of instructors who are competent both from a technical and a teaching standpoint. Due to the nature of the subjects taught, it is possible to group motor inspectors from various plant areas for these classes. Where and when classes are to be held and how many hours will be devoted to this instruction each week, are matters for local plant determination because of the differences in training needs and work schedules.

As in the case of any training program, the continued effectiveness of motor inspector training is dependent upon adequate follow-up on the job by the supervisor. Through daily observation and periodic reappraisal of performance, he is in a position to measure their progress and retrain them on certain parts of their job, if necessary. Moreover, the supervisor knows when new equipment or methods are established which require additional knowledge or skill on their part. His awareness of the training needs created by such changes makes it possible for him to keep his men's performance on a par with the requirements of the job.

So far we have highlighted some of our plans concerning the present group of motor inspectors. There still remains the second matter of concern, that of offering helpers an opportunity to acquire technical knowledge for their self-improvement.

We recognize that helpers naturally absorb considerable job knowledge and skill through working under the direction of the motor inspectors. Where all of the steps previously outlined have been taken, the improved performance of the motor inspector group should be reflected in the helper group. Adequate instruction and observation, day in and day out on the job, should provide helpers with much of the practical knowledge and skill needed in this area. However, the daily routine provides helpers with little opportunity to acquire the technical knowledge needed for self-improvement. For this reason, some plants have cooperated with local schools in establishing evening classes covering pertinent subjects. Participation in these classes is on a purely voluntary basis, in fact, they are open to any who care to enroll. In this manner, opportunity for self-improvement is offered members of the helper group.

In conclusion, we do not pretend to have all of the answers to this problem of training motor inspectors — or men in other assigned maintenance positions. We lay no claim to having discovered a new approach to such problems. We are simply applying the training principles that have produced good results for us in the past — and we feel that they will do the job for us again. Progress is being made in the area of motor inspector training, and before long, programs based on these principles should be established in other areas.

DISCUSSION

PRESENTED BY

ERIC TAYLOR, General Electrical Foreman, Atlas Steels, Ltd., Welland, Ont., Canada.

G. M. KENNEDY, *Coordinator of Apprenticeship and On-the-Job Training, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

*At time of paper presentation.

Eric Taylor: In connection with training classes for assigned maintenance men, we of course are a small company, and we find it impossible to take assigned maintenance men off their assignments during the shift hours. In other words, there is just not enough extra men to allow us to take these men away for the necessary length of time, when there is a session of that kind. It would have to be held outside of the regular assigned time, and I assume that under those conditions, you would find it necessary to have to pay these assigned men, an over-time basis for attending those classes.

I think a plan should be made for men to improve themselves technically by making available to these men, courses, either with correspondence companies, or with night classes. It should be entirely at the discretion of the man himself, provided that the course he wished to take, is along the lines of his duty, and it is approved by management on that basis. If he completes this course, which he takes at his own expense, the company should refund him, on the satisfactory completion of the course, any expense to which he has been put in taking it.

Should it become necessary for a man to leave the company through no fault of his own before the completion of such course, the company, on completion of such course should refund him such portion of the money he has expended while an employee at the plant. That is just a thought I might throw out, because we have 46 per cent of our electrical assigned maintenance men at present, engaged in courses of that kind.

G. M. Kennedy: In our company we have scheduled classes for four hours in the morning and for four hours in the afternoon during regular working hours. In case of an emergency the motor inspector is called from the class.

The answer to your question in reference to pay comes under the provisions of the Fair Labor Standard Act and should be discussed with your law department. However, required attendance at class outside of regular working hours would be considered time worked and paid for at overtime rates.

Eric Taylor: Then, if it is scheduled, you would have to pay overtime.

G. M. Kennedy: In the United States Steel Co. anything that is done on the employee's own time is purely voluntary.

Member: When we started our 30-in. strip, we were faced with the problem of training motor inspectors and millwrights, and everything else, and doing it as quickly as possible, and as thoroughly as possible, with the time remaining. In other words, we had to build an operation. We had to get as good a training program underway as possible, immediately. We started an "On The Job Training" for motor inspectors having the day turn who stay an hour overtime, and the four to twelve turn coming in an hour earlier. In training those motor inspectors, by taking them to a particular point and discussing and explaining the operation of a particular piece of equipment, as we did once a week, we covered all the unfamiliar types of equipment with those particular men. We supplemented that also by having a two-hour course at which they were paid for at the time they attended, and covered all shifts by arranging our schedule accordingly so that those men, in addition to getting their own job training, received a little bit of technical training as well. That not only covers the motor inspectors, but our millwrights' problems of rigging, tying knots, and lubrication for all maintenance personnel.

It is interesting to note the additional training which men get from the available courses. We have a considerable number of our maintenance personnel attending night school courses purposely on their own time and expense for their own development and education.

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BLAST FURNACE CONTROLLED SPLIT-WIND BLOWING

at

ALGOMA STEEL CORP.

By WILLIAM O. BISHOP
Technical Assistant — Blast Furnaces
Algoma Steel Corp., Ltd.
Sault Ste. Marie
Ontario, Canada

. . . . split-wind blowing offers advantages at plants where a number of smaller furnaces are to be blown . . . .

▲ SPLIT-WIND blowing of blast furnaces may be defined as the delivering of wind simultaneously to two or more furnaces from a common main as supplied by one or more units of blowing equipment. This method of operation is not new although it is rarely used in America where furnaces are built with their own individual blowing equipment. Occasionally a furnace plant will temporarily get out of balance, necessitating some type of split-wind blowing. Recently two furnaces were blown by three turbos at a Carnegie-Illinois plant in the Pittsburgh district. In this case as in others, the quantity of wind delivered to each furnace could only roughly be controlled. If the furnaces were of different sizes, if one furnace went on pressure, or if one furnace was on check, the difference between the required wind and that actually received by the furnaces was still further amplified.

In England, split-wind blowing was fairly common in the past. However, the newer plants operate on the single blower for a single furnace system. The common blowing is sometimes operated from the cold blast main and sometimes from the hot blast main. One example of the latter is contained in a report of January 1939, by the British Iron and Steel Federation of the Skinningrove Iron Co.'s No. 3 furnace which was producing basic iron from a mixed burden of Cleveland calcine and foreign ores. It was blown from a common hot blast main serving three furnaces at an average pressure of 7-8 psi. Nine stoves were connected to this common hot blast main.

During the war years, retired furnaces of small capacity were pressed into service and in some instances were blown common with another furnace on the line. In other cases, during periods of night air raid warnings, with the furnaces being fanned at around 2 psi pressure, split-wind blowing during the warning period was employed to safeguard the gas and steam balance. During these periods, however, this common blowing pertained to the cold blast main common to the furnaces concerned, with hot blast mains on all furnaces fully isolated. Control of pressure to the furnaces was attained by the setting of the stove cold blast valve or, in some cases, by means of a furnace valve located in the hot blast main adjacent to the inlet to the furnace bustle pipe.

A search of the literature on this subject reveals few published articles. With reference to Germany, The British Iron and Steel Research Association made a post-war survey, extracts of which are quoted from their Report on German Blast Furnace Practice and Plant, dated 1946.

"It is general practice to blow a number of furnaces from a common cold blast main due apparently to lack of correlation between individual blower capacities and individual furnace requirements; thus the blast mains are usually arranged for this method of blowing. In some cases volume control is available at each furnace when required by provision of regulators. Individual blowing has not been developed, and apparently is not so vitally necessary as in the United Kingdom because of the very high quality of Ruhr Coke.

"The turbo-blowers seen were mostly rated at 70,000 cfm and 18 psi pressure, but three large units were seen at Rheinhausen rated at 100,000 cfm and 18 psi pressure. Here again the blowers are designed to supply more than one furnace."

The German layout for controlled volume blowing unfortunately is not described in detail in the above quoted report, but does bring us to the current practice at Algoma Steel Corp., Ltd., Sault Ste. Marie, Canada. Our previous remarks on split-wind blowing generally omitted the word "controlled." It is now added to the definition to mean the properly proportioned and known quantity of wind being delivered to each furnace. The Algoma installation is the first in America and Britain to the best of our knowledge.

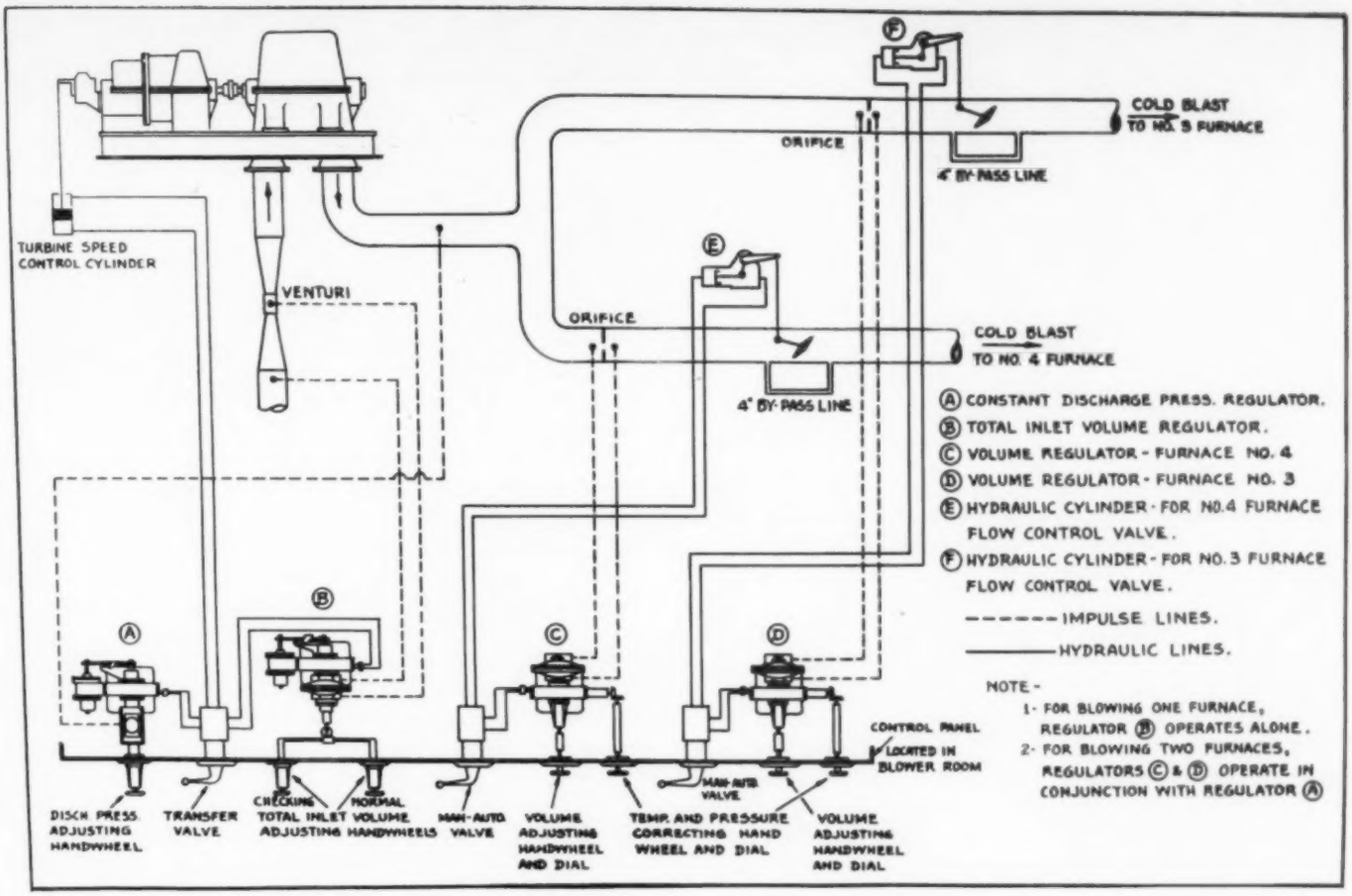

COLD BLAST TO NO. 3 FURNACE
ORIFICE
4" BY-PASS LINE
TURBINE SPEED CONTROL CYLINDER
VENTURI
ORIFICE
COLD BLAST TO NO. 4 FURNACE
4" BY-PASS LINE
(A) CONSTANT DISCHARGE PRESS. REGULATOR.
(B) TOTAL INLET VOLUME REGULATOR.
(C) VOLUME REGULATOR - FURNACE NO. 4
(D) VOLUME REGULATOR - FURNACE NO. 3
(E) HYDRAULIC CYLINDER - FOR NO.4 FURNACE FLOW CONTROL VALVE.
(F) HYDRAULIC CYLINDER - FOR NO. 3 FURNACE FLOW CONTROL VALVE.
IMPULSE LINES.
HYDRAULIC LINES.
NOTE -
1- FOR BLOWING ONE FURNACE, REGULATOR (B) OPERATES ALONE.
2- FOR BLOWING TWO FURNACES, REGULATORS (C) & (D) OPERATE IN CONJUNCTION WITH REGULATOR (A)
CONTROL PANEL LOCATED IN BLOWER ROOM
DISCH PRESS. ADJUSTING HANDWHEEL
TRANSFER VALVE
CHECKING TOTAL INLET ADJUSTING
NORMAL VOLUME HANDWHEELS
MAN-AUTO VALVE
VOLUME ADJUSTING HANDWHEEL AND DIAL
MAN-AUTO VALVE
TEMP. AND PRESSURE CORRECTING HAND WHEEL AND DIAL
VOLUME ADJUSTING HANDWHEEL AND DIAL

Figure 1 — General arrangement of controls for split-wind operation.

LOCAL BACKGROUND

The Algoma blast furnace plant consists of five furnaces with these hearth diameters: No. 1 — 12 ft 7 in., No. 2 — 12 ft 6 in., No. 3 — 17 ft 9 in., No. 4 — 15 ft 9 in., and No. 5 — 25 ft 0 in. They were blown until January, 1950, by four vertical steam engines, two 10,000 cfm electric driven compressors, five horizontal gas driven blowers, and one 75,000 cfm steam driven turbo-blower. Table I shows the combination of wind and equipment on the furnaces. With the exception of the compressors (a war-time purchase) and the turbo-blower, the equipment was old, badly worn, generally obsolete, expensive to maintain and operate.

In the fall of 1948, the company decided to modernize the blowing equipment for No. 3 and 4 furnaces. Normally this would have meant two new relatively small turbo-blowers, one for each furnace. If only one additional 75,000 cfm turbo could be purchased, the overall installation cost would be less, the spare parts

TABLE I

COMBINATION OF BLOWING UNITS PRIOR TO CONTROLLED SPLIT-WIND BLOWING

Blowing units	Blast furnaces				
	No. 1	No. 2	No. 3	No. 4	No. 5
Steam engines	2½ 29,250	1½ 17,550	.....	.....	.....
Gas engines	.....	.....	2 38,400	2 38,400	.....
Electric compressors	.....	1 10,000	1 10,000	.....	.....
No. 1 Turbo-blower	.....	.....	.....	.....	68,000
Total theoretical wind blown — cfm	29,250	27,550	48,400	38,400	68,000
Note — One gas engine held as spare — capacity 15,600 cfm.					

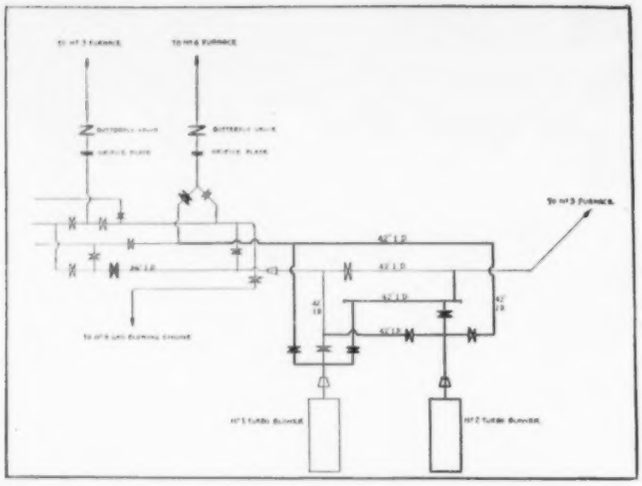


Figure 2 — Sketch shows additional cold blast main construction and valving.

situation simplified, and operating units reduced. It was emphasized that there must be a positive control of the wind to each furnace under any possible combination of operating conditions. Even more important, the installation must be safe and generally fool-proof, which meant that each furnace snort valve must always be under air pressure on the turbo side, again regardless of working conditions on the other furnace. This last point was stressed to prevent explosions in the cold blast main as a result of minor furnace kicks. The combined thoughts of all concerned resulted in the general layout show in Figure 1.

A year later in the fall of 1949, the installation of the new turbo commenced together with alterations to the blowing room and cold blast mains. Figure 2 shows the additional cold blast main construction and valving. In December 1949, the control panel was installed and by early January 1950, the equipment was ready for trial runs.

LAYOUT AND CONTROLS

The installation consisted of a new 75,000 cfm turbo-blower with venturi air intake, a discharge pressure tap and temperature bulb in the turbo discharge, a relief line adjacent to the turbo discharge, a check valve, and a cold blast header main with various cross connections and suitable gate valves so that either turbo-blower could be used, although the older one had no instrumentation for split-wind. To this point, no difference is apparent with a routine "single blower for single furnace" set-up, but here the similarity ends. In the cold blast main to No. 3 furnace, first from the header main, there is an orifice plate for air flow measurement, next a piston-operated butterfly valve with a specific minimum closing point and for additional safety a by-pass line, then a pressure tap, and finally the snort valve. A similar system led to No. 4 furnace, as shown in Figure 1.

The venturi taps on the turbo inlet lead through impulse lines to a total inlet volume regulator having a two speed adjustment (normal and checking) common to most single furnace turbo blown operation. This inlet volume regulator is connected to the turbine speed control cylinder (which activates the turbine governor) by means of hydraulic lines. A transfer valve on these lines permits changing from the inlet volume regulator to the discharge pressure regulator which, in turn, is controlled through an impulse line by the header main pressure. This latter regulator is used for split-wind blowing.

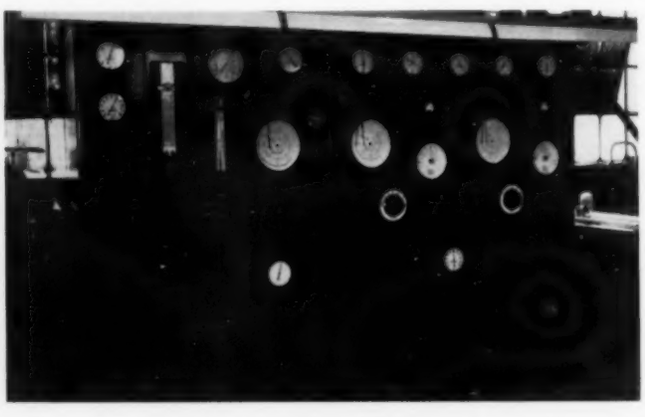
The taps on either side of the orifice plate in No. 3 cold blast main lead to a volume regulator with a temperature-pressure corrector, through a manual-automatic valve, and back to the piston operating the butterfly valve. No. 4 has a similar arrangement. These controls are mounted on the panel board in the blowing room as shown in Figure 3 which is a general view, and in Figure 4 which is a close-up.

In addition to these controls, the following recorders are also mounted: turbo air discharge temperature and pressure and inlet volume, No. 3 furnace pressure and volume, and No. 4 furnace pressure and volume. A No. 3 and a No. 4 temperature and pressure correction dial are in full view of the operator as are the butterfly valve position indicators. The other gages pertain to the turbo and are common to any other such installation. The layout sketch (Figure 5) identifies the individual equipment.

For single furnace operation, the pressure-volume

Figure 3 — Turboblowing room at Algoma Steel Corp., Ltd. with No. 1 turbo and controls at right, No. 2 turbo at left, and control panel in center.

Figure 4 — Control panel for No. 2 turbo blower shows split-wind controls for No. 3 and 4 furnaces.



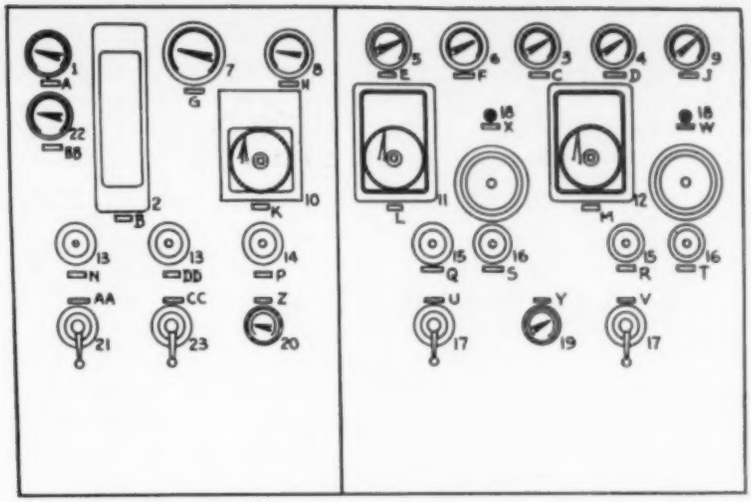


Figure 5—Panel layout shows location of instruments and controls.

LEGEND

1- BEARING OIL PRESSURE 6" 0 TO 30 PSIG.
2- VOLUME GAUGE I.R. CO.
3- FIRST STAGE STEAM PRESSURE 6" 30" HG TO 300 PSIG.
4- STEAM PRESSURE 6" 0 TO 600 PSIG.
5- STEAM SEAL PRESSURE 6" 0 TO 15 PSIG.
6- VACUUM 6" 0 TO 30" HG VACUUM
7- TACHOMETER 8½"
8- AIR PRESSURE 6" 0 TO 60 PSIG.
9- STEAM TEMPERATURE 6" AMERICAN #64703M
10- BRISTOL - 3 PEN RECORDER
11- BRISTOL - 2 PEN RECORDER
12- BRISTOL - 2 PEN RECORDER
13- ASKANIA - TOTAL VOLUME REGULATOR
14- ASKANIA - PRESSURE REGULATOR
15- ASKANIA - VOLUME ADJUSTMENT HANDWHEEL.
16- ASKANIA - TEMP. & PRESS. CORRECTION HANDWHEEL
17- ASKANIA - MANUAL-AUTOMATIC VALVES
18- SIGNAL LAMPS - VALVE WIDE OPEN
19- REGULATOR OIL PRESSURE GAUGE 6" 0 TO 200 PSIG.
20- OIL LEVEL INDICATOR FOR RESERVOIR I.R. CO.
21- BY-PASS CHECK VALVE FOR TOTAL VOLUME REGULATOR TYPE A152
22- MAIN OIL PUMP PRESSURE 6" 0 TO 100 PSIG.
23- TRANSFER VALVE (FROM PRESS. TO VOLUME REGULATOR) TYPE A151

NAMEPLATES

A- BEARING OIL PRESSURE
B- VOLUME
C- FIRST STAGE STEAM PRESSURE
D- STEAM PRESSURE
E- STEAM SEAL PRESSURE
F- VACUUM
G- SPEED R.P.M.
H- AIR PRESSURE
J- STEAM TEMPERATURE
K- DISCHARGE TEMP. & PRESSURE - INLET VOLUME
L- PRESSURE & VOLUME - FURNACE NO. 3
M- PRESSURE & VOLUME - FURNACE NO. 4
N- TOTAL VOLUME REGULATOR - CHECKING.
P- PRESSURE REGULATOR
Q- VOLUME - FURNACE NO. 3
R- VOLUME - FURNACE NO. 4
S- TEMP. & PRESS. CORRECTION - FURNACE NO. 3
T- TEMP. & PRESS. CORRECTION - FURNACE NO. 4
U- FURNACE NO. 3
V- FURNACE NO. 4
W- FURNACE NO. 4 - VALVE OPEN
X- FURNACE NO. 3 - VALVE OPEN
Y- REGULATOR OIL PRESSURE
Z- RESERVOIR OIL LEVEL
AA- VOLUME REGULATOR CHECK VALVE
BB- MAIN OIL PUMP PRESSURE
CC- REGULATOR TRANSFER VALVE
DD- TOTAL VOLUME REGULATOR - SETTING.

transfer valve is set for volume, the butterfly valve to that furnace is locked in the open position by means of the manual-automatic valve, the cold blast main gate valves are set as required and normal volume blowing proceeds.

For controlled split-wind blowing, the transfer valve is set for pressure, and the constant discharge pressure regulator is adjusted to furnish the desired header main pressure which is a pound or two above the highest normal furnace pressure, but in our case not over 22 psi. The turbo will automatically maintain the pressure. The volume controls on each furnace are then set for the wind volume ordered by the foreman. The blowing room operator makes the necessary temperature-pressure adjustments on the furnace volume regulators

TABLE II

COMBINATION OF BLOWING UNITS AFTER INSTALLATION OF CONTROLLED SPLIT-WIND BLOWING

Blowing units	Blast furnaces				
	No. 1	No. 2	No. 3	No. 4	No. 5
No. 1 Turbo-blower	.....	.....	.....	.....	68,000
No. 2 Turbo-blower	.....	.....	40,000	29,000	.....
Gas engines	1¼ 24,960	1¼ 26,240	.....	.....	.....
Total theoretical wind blown — cfm	24,960	26,240	40,000	29,000	68,000

Note — 4 Steam engines, 2 gas engines, 2 electric compressors now held as spares.

based on turbo discharge pressure and temperature every hour, or as changes are ordered.

The signal system between furnaces and blowing room is the usual variety. It consists of an electric push button at the furnace which blows a siren and lights a signal light in the blowing room. Standard dial telephones from the central exchange are also located in each pyrometer room and the blowing room.

FURNACE OPERATION

No difficulty has been experienced to date on No. 3 and 4 furnaces. Should one furnace have to be checked, the blowing room operator adjusts the volume control on that furnace downward as ordered by the furnace foreman. The cold blast main butterfly valve closes the required amount. Should the request be for "wind off," the volume is reduced to the minimum set for this plant, the butterfly valve will close to the minimum, snort valve is opened and the furnace drafted in the usual manner. It will be noted that the butterfly valve closes only to 5 degrees; further, the 4-in. by-pass line is always open, so that air pressure is always against the snort valve as a safety measure.

Should the furnace pressure rise to that held in the header main, any additional rise results only in reduced wind to the furnace. Should it be desired to maintain the same wind, the turbo pressure is adjusted upwards and this can be carried to the limit of the turbo capacity, i.e. 30 psi. Obviously, this is a matter of individual plant policy. A test on our installation showed the turbo capable of 90,000 cfm at 30 psi. The proper wind reached one furnace on pressure at 28 psi with the other furnace not affected. Naturally the lower the header pressure is held in relation to the normal working pressure on the furnaces, the more economical the turbo operation. Figure 6 shows operating charts illustrating these conditions.

It might be pointed out that the sum of the volumes shown on the No. 3 and 4 charts does not total that on the turbo chart. This discrepancy occurs because the various recorders are not corrected for the variations in temperature and pressure and because of a multitude of valve and main leaks. If correction factors are applied, the charts agree to within 5–10 per cent. The wind to the furnaces, of course, is correct at standard conditions of 60 F and 30 in. of Hg due to the adjustments made by the blowing room operator. The only possibility of error in wind between the orifice plates and the furnace tuyeres would be leaks in that section of mains including the stoves.

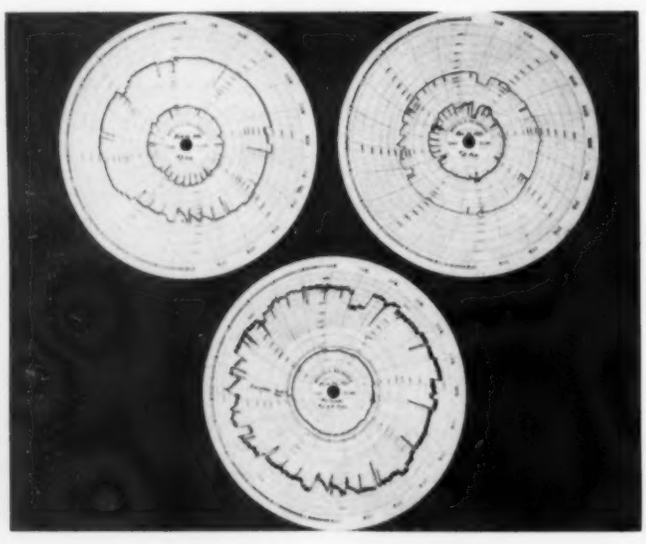
A third case in connection with the turbo itself can result when the wind required for the furnaces is so low that it may put the turbo in the pumping stage. It has been found necessary here to link the turbo relief valve on the blow-off line with an additional regulator which operates off the venturi inlet, for automatic operation. This regulator is mounted to the left of the instrument panel board. It is set to open and maintain a minimum flow of 35,000 cfm (which is just above the pumping stage) to the turbine and has been quite satisfactory.

Table II shows our present combination of blowing equipment. The decrease in wind on No. 3 and 4 furnaces is the usual result if replacing over-rated reciprocating equipment with modern turbo-blowers.

It might be mentioned that No. 3 furnace is generally on malleable iron with average pressures of 16.0 psi, and No. 4 furnace is on foundry iron with average pressure of 15.5 psi. No change has been noted on the furnace practice with reference to present and past methods of blowing.

The controlled split-wind blowing has been in continuous operation on these furnaces since February 1950.

Figure 6 — Pressure-volume charts illustrate various furnace conditions.



GENERAL COMMENTS

In every new installation there are some "bugs" to be worked out. These generally have been of a minor nature, but it might be pointed out that it is necessary to have a proper cold blast main layout before optimum operation can be obtained. In this respect, location of the orifice plates is of the utmost importance.

There has been fortunately no need to tie in reciprocating blowing equipment with the turbo, but it is questionable whether the pulsations produced by this type of blower will give satisfactory results. These pulsations may produce an unwanted fluttering effect on the butterfly valves unless a suitable damping device can be incorporated.

Blowing costs on No. 3 and 4 furnaces have been reduced at least 25 per cent although obviously this can be attributed only partially to split-wind operation. The turbo replacing the older units was a big factor. It can be stated that the steam consumption and cost of operation of the new turbo is very close to its twin on No. 5 furnace. The cost of split-wind installation is relatively small and we consider it well worthwhile.

A thought for the future is the placing of both turbos on a common cold blast header main and adding No. 2 furnace to the system with controls all along the line. This will utilize the remaining capacity of the turbo-blowers and eliminate additional old equipment with obvious savings.

DISCUSSION

PRESENTED BY

W. H. COLLISON, Supt. Coke Plant, Blast Furnace Div., Great Lakes Steel Corp., Ecorse, Detroit, Mich.

W. O. BISHOP, Technical Assistant - Blast Furnaces, Algoma Steel Corp., Ltd., Sault Ste Marie, Ontario, Canada.

F. P. MacNAUGHTON, General Superintendent Blast Furnaces, Rouge Plant, Ford Motor Co., Dearborn, Mich.

W. H. Collison: It seems that split-wind blowing affords certain advantages to older plants where a number of smaller furnaces are to be blown. I question whether it would be an advantage in a plant with larger furnaces or where high pressure blowing enters into consideration. Have you projected your consideration of split-wind blowing to where it would cover high pressure blowing?

W. O. Bishop: Where you have one furnace which you want to run on high blast pressure of, say, 25 or 26 psi, and you have another furnace which would be on normal pressure of 17 psi you would have to run your turbo-blower at a cold blast main pressure which would match that of the higher pressure furnace. Now, that is uneconomical from the standpoint of blowing the furnace with the lower pressure, and you will find that it will cost you something to do that. The controls are such that it can be done. We proved that when we first made the installation, at which time one furnace went on high pressure and the other ran normally, we knew that the wind was properly delivered. It is the cost element then that enters into it. The most economical split-wind operation is obtained on furnaces having the same average pressures, whether low or high.

F. P. MacNaughton: What will be done when one of the furnaces is shut down. Do you still have your old installation for that furnace?

W. O. Bishop: The new installation did not actually change the cold blast main system. Should you take one of the furnaces off, which is on split wind — in other words, run the turbo-blower only on one furnace — we would just shut the gate valve in the cold blast main to the furnace which is down and blow directly by volume to the remaining furnace as you normally do on a single blast operation.

Jet Tapping of Open Hearth Furnaces

By H. H. NORTHRUP

Superintendent, Open Hearth Dept.

Republic Steel Corp.

Buffalo, N. Y.

. . . . explosives may be used to tap open hearth furnaces with economy and safety over the oxygen lance method . . . .

▲ THE taphole of an open hearth furnace is usually 6 to 8 in. in diam and approximately 5 ft long. Before charging the furnace, this hole is filled with crushed dolomite and sealed on the outside with a plug of clay. When the heat is ready to be tapped, the second helper removes the plug and rakes out the crushed dolomite. The material on the hearth side of the taphole has become impregnated with metal and is usually exceptionally hard. Prior to about thirty years ago, this crust was broken by sledging on the end of a long bar which was inserted in taphole from the back of the furnace. This was a long and laborious task, and the hazards of burns from the gushing molten steel, once the crust was broken, was responsible for serious injury. Around the year 1920, it was discovered that oxygen, introduced through a long pipe or lance, could be used effectively to burn through the metallic impregnated dolomite crust. This method, used to date in most open hearth shops, has its drawbacks and hazards. The hole burned through the thick crust of the taphole facing may be so small that the flow of metal will freeze in the stopper well on the bottom of the ladle, resulting in

Figure 1 — The jet tapper has a 2-ounce explosive charge.

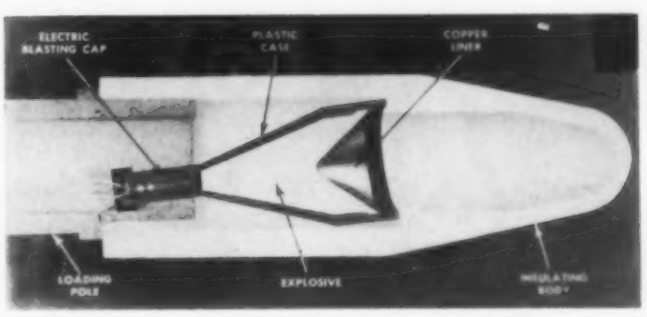


Figure 2 — The first step in the assembly is to thread the lead wires through the loading pole.

teeming troubles. It may mean that furnace crews must insert many long 1½-in. square steel bars through the peephole of the middle door of the furnace, down through the bath of metal in an attempt to break through the crust from the front of the furnace. Alloy additions to the heat are continually oxidizing during these minutes of delay, leaving the melter to guess the amount of alloy to add to overcome the unexpected oxidation loss and make the steel within chemical specification. Likewise, a delay of one minute means an

Figure 3 — The extension cord has a shunt on the end to prevent possibility of stray currents setting off the blasting cap prematurely.

appreciable monetary loss when we realize the value of a furnace hour today.

While working on a blast furnace problem early in 1947, Dr. B. S. Old felt that blast furnace men were unduly exposed to danger when lancing the furnace iron notch in spite of all safety precautions and equipment. He conceived the idea of using a shaped explosive charge generally similar to that used in the war head of the bazooka but suitably modified for the intended use and effectively protected against damage or premature detonation by heat of the taphole. He took the idea to an explosives company who had done most of the war-time development on this type of explosive charge. From this work, a jet caster was produced which successfully opened the iron notch.

During the experiment with blast furnace casting, it was thought that this new method might have even more possibilities in the open hearth, where tapping delays caused somewhat more trouble than in the blast furnace. The experimental work on the jet tapper was carried out at the Warren district of the Republic Steel Corp. The proper size and shape of the jet tapper was

Figure 4 — The protruding cord is taped to the end of the loading pole.

determined, the necessary safeguards applied and then it was turned over to the operators. Before its use, all operators were shown its design, parts, and safe methods in handling. The use of jet tapper was put on a voluntary basis and advantages stressed. Within a month, all helpers were using the tapper and bragging about results on their individual furnaces.

The jet tapper consists of a 2-oz explosive charge enclosed in a plastic case. See Figure 1. In the back of the case is a well for the blasting cap, while the key to the penetrating power lies in the thin copper cone which is embedded in the front of the case. The entire case is covered by a bullet shaped insulating shell ½ in. thick. The charge, is relatively less sensitive to impact or friction

than most commercial explosives, and will not detonate, but only burn if heated to a sufficiently high temperature. In one test, a case of 24 jet tappers was thrown on a bonfire with no sign of any violent reaction. An impact test was made by placing six tappers side by side between two steel plates and dropping a 150-lb weight on them from a height of nine feet. The completely crushed charges showed no evidence of detonation. The jet tappers are detonated by a special high temperature blasting cap, inserted in the well in the back of the plastic case containing the explosive. The insulating body surrounding the charge and cap insures a time interval of 3 to 8 minutes before the heat of the taphole will disintegrate the explosive charge or will detonate the blasting cap. The blasting cap lead wires are glass insulated for protection. It was found necessary, during experimentation, to slightly incline the charge in the insulating body in order to be sure the jet did not shoot into the furnace bottom. While this would not injure the bottom to any extent, it would not assure the opening of the taphole.

The explosive of the jet tapper, when detonated, creates a high velocity jet of minute copper particles from the cone, with velocities of individual particles ranging from 10,000 to 30,000 fps or as great as ten times the speed of a rifle bullet. The enormous energy built up by the jet of high speed particles upon impact with the taphole facing, causes the metallic crust to flow, almost like liquid, away from the path of the jet. The successive impacts of the particles gradually deepen the hole until the energy is expended. As we shall see later, the strength of the charge is proportioned so as to cause no damage to the taphole structure and penetrate only to sufficient depth to bring the heat. The diameter of the hole produced, depends on the temperature of the crust. Tests have shown the jet tapper to produce a hole approximately $\frac{3}{8}$ in. in diameter in cold steel, while in steel heated to 1500 F the same charge would produce a hole one inch in diameter.

The jet tappers are received in our plant in three separate units: the tappers assembled in insulating bodies, which are stored in a large New York state licensed magazine; the electric blasting caps, which are stored in another licensed magazine and the 8-ft long spiral wound paper tube loading poles which are stored in a dry space near the assembly room. The assembly is made by one man, who gets a daily supply of tappers and caps from their respective magazines and brings them to the assembly room located at one end of the charging floor.

Figure 2 shows how the assembly begins with threading the cap lead wires through the loading pole.

The lead wires are connected to a reusable extension cord (Figure 3) which has a shunt on the end to prevent the possibility of stray currents passing through the blasting cap. This is standard procedure in blasting operations.

The connections are taped to opposite sides of a cardboard strip (Figure 4) and inserted in the end of a loading pole and the protruding cord taped tightly to the end of the loading pole.

The shunt is then removed and the circuit tested with a blasting galvanometer after which the shunt is replaced. See Figure 5.

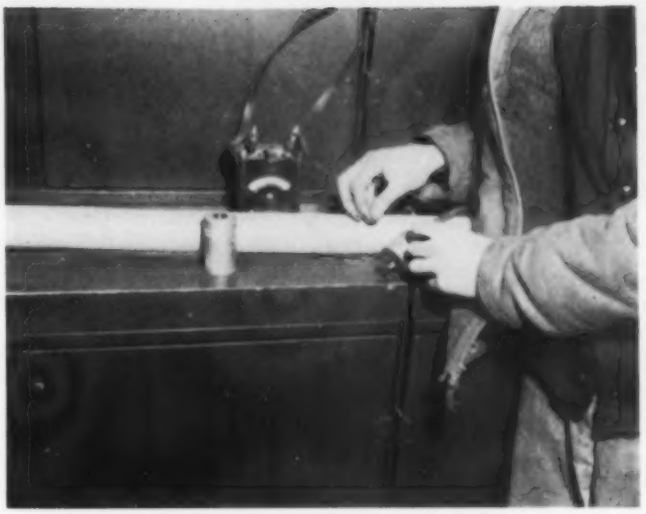


Figure 5 — A galvanometer is used to test the blasting circuit.

The electric blasting cap is inserted into the well provided at the rear of the plastic cone containing the explosive and a cap well cover put in place, as shown in Figure 6.

The insulating head is then fitted over the end of the loading pole. See Figure 7.

After assembly, the daily supply of tappers are placed in three storage cabinets located on the open hearth charging floor, as shown in Figure 8.

The firing circuit in back of the furnace is installed to eliminate any possibility of premature detonation. This circuit consists of a receptacle approximately 10 ft from the taphole with leads through an interrupter switch to a shop twist type blasting machine.

When the heat is ready to tap, the melter, who alone has the key to the storage cabinet, gets a jet tapper and the blasting machine from the locked storage cabinet on the floor. After the dolomite has been removed from the taphole, the melter attaches the blasting machine

Figure 6 — The electric blasting cap is inserted at the rear of the plastic cone containing the explosive.

to the firing circuit leads, giving the portable handle to the second helper. With this handle in his pocket as an added safety precaution, the second helper inserts the jet tapper into the taphole as far as possible. He then walks to the receptacle, removes the short circuiting switch from the extension cord and plugs into the firing circuit. The circuit is still shunted by virtue of the interrupter switch at the firing station. By inserting the handle into the blasting machine and twisting, while at the same time depressing the interrupter switch button with the other hand, the charge is detonated some thirty feet away. These precautions are taken to prevent any premature energizing of the firing circuit. The blasting cap may be fired by a current of less than 1 amp. After firing, the end of the extension cord can be recovered and reused.

Should the charge fail to fire, it should not be removed from the taphole. The heat of the taphole will detonate the blasting cap within 3 to 8 minutes and explode any of the remaining charge. In a case such as this, the tapper may not penetrate the taphole facing, as much of the explosive has deteriorated from exposure to heat.

When a charge has been fired and does not bring the heat, an oxygen lance is generally used to open the taphole. It is not recommended that the second helper use the jet tapper if he feels that the facing of the hole is soft or that the heat may break out.

In an effort to simulate a condition where the heat would break out while the unfired jet tapper was in the taphole or being placed in the hole, several tests were made to find the length of time required for a temperature detonation of the cap immersed in molten steel. These tests consisted of making up units with a dummy charge, but with a live cap, and throwing them into the ladle as it was filling with steel. The units floated on the surface of the molten steel and slag from 1 to 3 minutes before detonating the cap.

The jet tapper is now used on all heats tapped at the Buffalo, N. Y. and Warren, Ohio plants of Republic Steel Corp. with approximately 85 per cent of them bringing in the heat.

The failure of charges to effect a good tap can usually be traced to failure of the second helper to thoroughly rake out all the loose material in the taphole or a short taphole caused by an abnormal penetration of metal and slag. Our experience has shown that with a properly raked out taphole and the jet tapper resting against the crust of the taphole facing; a good tap is effected with the following advantages:

Figure 7 — An insulating head fits over the end of the loading pole.

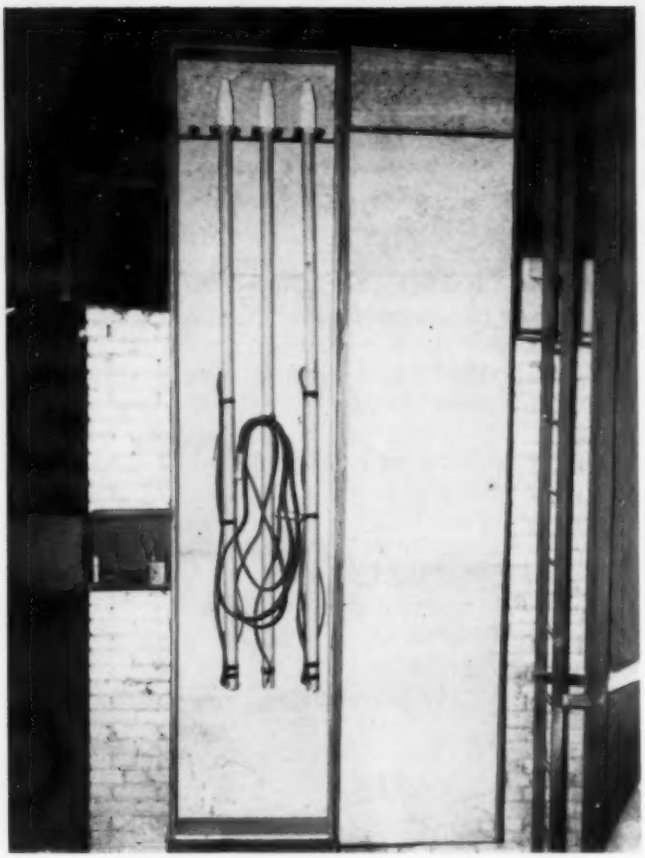


Figure 8 — The daily supply of tappers is kept in storage cabinets located on the open hearth charging floor.

1. It helps a melter tap his furnaces fast without the usual fear of hard taps where a delay with two or three oxygen lances means additional oxidation of alloy additions in the bath. The arrival of a full stream almost immediately results in a 2 to 3 minute faster tap and causes less skulling in the nozzle well of the ladle. The elimination of small ladle skulls means cleaner pouring.
2. The jep tapper has almost eliminated the use of tapping rods. While these rods, after use, have a scrap value, the savings effected by their elimination alone can almost pay for the jet tapper. Furnace crews have credited the jet tapper with the reduction in that hard part of their work of lifting and using tapping rods.
3. Taphole maintenance has been reduced with the use of the jet tapper. When using an oxygen lance, the second helper must stand at one side of the taphole, which practice tends to burn the face of the hole at an angle. Since using the jet tapper, the center line of the taphole has remained much nearer to the center line of the furnace. There have been no detrimental effects to taphole refractories with the jet tapper.

Production of the jet tapper has heretofore been limited because of its experimental use, but with over 2000 units nowhaving been fired and with the manufacturer expanding his production facilities commensurate with the demand from the field, other open hearth shops may now take advantage of the new improved tapping method.

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PLAIN BEARING RECOMMENDED PRACTICE

AISE RECOMMENDED PRACTICE NO. 1

APRIL 29, 1951

(TENTATIVE)

Foreword by C. E. Pritchard

▲ In September, 1945 the Association of Iron and Steel Engineers set up a committee to develop a specification for steel plant bearings. This specification was limited to plain bearing applications. It was at first thought a fairly simple short set of rules could be developed, which would be used as a guide for such a standard. However, because of the large number of varied applications in the steel plant, ranging from the smallest to the largest bearings used in any industry, the relatively brief standard first developed progressively grew. In addition, the variations in operating conditions and practice made the committee decide that it would be better not to set up a rigid standard, but to develop what will be called a recommended practice which may be used as a guide to the designers, operators and men maintaining steel plant equipment. It is believed that the recommended practice which has developed is a worthwhile contribution to the steel industry. One of the objects in setting up this practice is to stimulate discussion and further research on plain bearings. The results of such work when compiled and evaluated through the lubrication groups of Association of Iron and Steel Engineers will help in obtaining better operating conditions throughout the steel industry. Such work should result in obtaining some of the missing answers which are not outlined in this practice, and it is hoped that some of this data will be forthcoming so that it may be issued when next this bearing practice is revised.

The writer acknowledges with thanks the cooperation of the other members of the committee whose help was responsible for the successful completion of this project. The plain bearing committee consists of the following members:

C. E. Pritchard, Chairman, Chief Lubrication Engineer, Republic Steel Corp., Cleveland, Ohio.

W. E. Hyde, Lubricating Engineer, Wheeling Steel Corp., Steubenville, Ohio.

H. L. Smith, Federated Metals Division, American Smelting and Refining Co., Pittsburgh, Pa.

Otto Riss, Cleveland Graphite Bronze Co., Cleveland, Ohio.

H. H. Wood, District Manager, Morgan Construction Co., Pittsburgh, Pa.

D. E. Whitehead, General Lubrication Engineer, Crucible Steel Co. of America, Pittsburgh, Pa.

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1. Introduction

In the operation of machinery and equipment employing plain bearings throughout the various stages of producing and finishing steel and its allied products, the efficiency of the given operating unit depends to a large extent upon the loss in power of the moving parts, the rate of bearing wear, and maintenance costs. In any operating unit there is to be found an attendant frictional resistance that is converted into heat, which in turn results in a loss in power. It is easily seen, therefore, that where the fundamentals of good bearing practice are known and followed, a low coefficient of friction is maintained between the bearing material and the moving member. The control of this rate of wear, experienced on all bearing installations to a greater or lesser degree, is of paramount importance when measured in terms of availability of the machinery for continuous and uninterrupted production. It has also been found that as a matter of convenience and basic economy, this given wear should always take place on the least costly and most easily replaceable part, such as the bearing. Most engineering design is predicated upon this proven fact, but due caution must be exercised to insure the bearing material possesses sufficient mechanical strength to carry the imposed load while also providing the other desirable bearing properties.

A wide range of bearing materials has been used in plain or journal bearings as they are oftentimes referred to throughout the steel industry. Included in this extensive range of coverage are the high lead base babbitts, high tin base babbitts, phosphor bronzes, leaded bronzes, aluminum bronzes, manganese bronzes,

sintered bronze, sintered iron, aluminum alloy, cast irons, gray irons, composition (phenolic-resin type), hardened steel (nitrided or hard surfaced), mild steel, carbon-graphite, cadmium-nickel, copper-lead, plastic, glass, wood, and several others of lesser importance. Quite often the materials are employed in the neat form, but most generally are used in combination with one or more of the other bearing materials as dictated by the service conditions. For example high operating temperatures may be encountered which are found to exceed the upper limits of the conventional type bearing materials and lubricants. In order to meet this extreme condition in an economical manner, nitrided bushings and nitrided pins or journals are sometimes employed without any lubricant being applied. Due to the relatively hard surfaces involved, very little wear is found to exist. On the other hand, usage of the high leaded bronzes offers a means of better meeting the requirements imposed upon operations due to lack of adequate lubrication. In this case the self-lubricating characteristics of this type bearing material tends to extend the expectant service life of the given bearing installation considerably beyond that of conventional brass or bronze, operating under similar conditions. In the case of the phenolic or carbon-graphite type materials, water only is sometimes employed as the coolant and lubricant. Where lubricant contamination cannot be tolerated such as in plating or pickling lines, the bearing material must operate dry or utilize the solution in question as a lubricant medium despite its acidic properties. Thus it may be clearly understood that no general recommendation will suffice for most applications, but rather a complete and thorough study of all the factors involved should prevail if the most efficient material and practices are to be realized.

The choice of the most suitable material for the purpose intended in the specific applications is found to be subject to debate by the various designing engineers, due primarily to their individual range of experiences. The object of the present work is to correlate the available data covering the fundamental requirements of good bearing practice, and all its many ramifications, which when properly disseminated should be helpful to persons responsible for the design, operation, and maintenance of properly lubricated journal bearings.

Evaluation of the performance of bearing materials in general is found to be quite complex due to the many variables encountered in field practice, past experience dictating to a major extent the actual selection made. One of the most common errors known to exist in this regard is that of overlooking the human element problem. In all such evaluations, it is believed to be mandatory that due consideration be allowed for the human element factor. Where precise and accurate fits are required it becomes necessary to provide a higher calibre installation and maintenance man than would be required where greater tolerances are permitted. Likewise, in selecting the proper bearing material for a specific bearing installation, all such contributing factors must be included. Despite these obvious limitations, the designer, through published literature, has at his disposal a wealth of information concerning the advantages of the materials best suited for his individual bearing requirements.

The selection of a bearing material is actually, in most cases, a compromise because no single composition has been found which will have perfect performance for all bearing applications. In making the most desirable selection, the designing engineer or maintenance man must first have a thorough knowledge of the relative importance of the requirements for satisfactory service. In addition, he must also understand the limitations of the numerous available materials and select the one that best meets these established requirements.

In discussing and evaluating bearing requirements, a number of pertinent facts must be considered, including the fundamentals of bearing friction; beneficial effects of lubricants on the bearing surfaces; fundamentals of oil film formation; fundamentals of oil grooving and sealing; bearing calculations; fundamentals of bearing mountings; bearing design influence on machine vibration; bearing load ratings; bearing properties; machining practices and actual field application experiences. These will be covered in some detail in order that a better understanding of the factors, upon which optimum bearing performance depends, can be more clearly recognized by those individuals charged with the responsibility for satisfactory bearing service in the steel industry.

Although it is recognized that the usage of grease for lubrication of plain bearings predominates throughout the industry, at the present time it was found impractical to include the subject in this write-up, due to the fact that it has not been properly correlated with field experience in the plants which make up the steel industry. Further experience may develop the correlations upon which proper grease application can be based. When this information is obtained by the industry, it will be incorporated in a revision of this practice.

Design values for bearings will depend a great deal on both the use to which the bearing is to be put, and to the precision with which the bearing is manufactured. In the following work, bearings will be divided into four general arbitrary classifications. Where data given is not applicable to all classifications, notations will be made to which type of bearings are covered. The four classifications are:

1. Precision bearings consisting of those under 8 in. in diameter which are used in automotive, diesel engine, precision spindles, special tools and applications of this type
2. The second classification comprises the large diameter oil-flooded lubricated precision bearings normally used for roll neck applications.

Figure 1 — No matter how smooth the surface may appear, it still consists of projections and indentations.

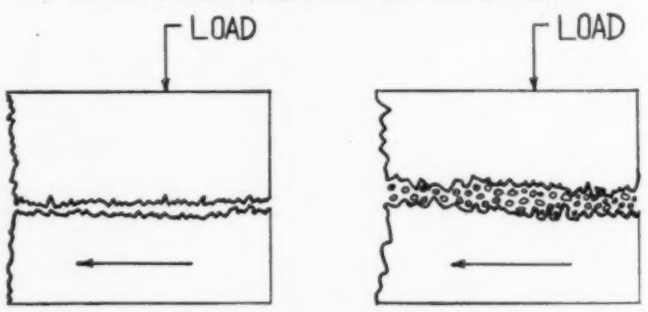


TABLE I (11)

COEFFICIENT OF SLIDING FRICTION FOR CLEAN DRY SURFACES

Determined at low velocities, representative of static friction

	Hard steel	Mild Steel	Platinum	Nickel	Copper	Brass	Aluminum	Tin	Lead	Glass
Hard Steel	0.39	....	....	....	....	....	....	....	....	....
Mild steel	0.41	0.41	....	....	....	....	....	....	....	....
Platinum	0.40	0.43	0.45	....	....	....	....	....	....	....
Nickel	0.43	0.43	0.39	0.39	....	....	....	....	....	....
Copper	0.55	0.53	0.50	0.56	0.60	....	....	....	....	....
Brass	0.54	0.51	0.56	0.50	0.62	0.63	....	....	....	....
Aluminum	0.65	0.61	0.80	0.75	0.70	0.71	....	....	....	....
Tin	0.79	0.77	0.86	0.90	0.88	0.75	0.91	1.11	....	0.94
Lead	1.96	1.93	2.07	2.15	1.95	2.11	2.0	2.20	3.30	2.40
Glass	0.61	0.72	0.57	0.78	0.68	0.87	0.85	....	....	0.94

Note: At low velocities and with clean surfaces the coefficient of sliding friction and static friction do not differ appreciably.

3. The third classification covers medium bearings such as those used on pumps, compressors, motors, turbine generators, modern mill tables, finishing machines and applications of that type.

4. The fourth classification comprises loose fit bearings such as the old style and modern composition roll neck bearings, mine machinery, railroad, old style roll table bearings and applications of this type.

This classification is arbitrary.

2. Fundamentals of Bearing Friction

When two objects are in contact and moving relative to each other, a frictional force is generated at the contact surface. Surfaces that are apparently smooth to the eye actually consist of microscopic indentations and projections which tend to interlock when one surface slides over another. See Figure 1. In a properly lubricated bearing, the surfaces are separated sufficiently to prevent such interlocking.

The frictional force (F) is the product of the coefficient of friction (f) that exists at the contact surface and the normal load (W) acting on the surface.

$$F = Wf$$

When the two objects are a rotating shaft and a stationary bearing, rather than the two surfaces mentioned previously, the frictional force will be a tangential force on the shaft tending to retard its rotation. The power input necessary to overcome this imposed frictional force may be calculated as follows:

$$Hp = \frac{f \times W \times D \times N\ (3.1416)}{396{,}000}$$

or

$$Hp = 0.000008 \times f \times W \times D \times N \qquad (1)$$

(7)*

where

f = coefficient of friction of the bearing
W = total load on bearing in pounds
D = diameter of shaft in inches
N = number of revolutions per minute of the shaft
Hp = horsepower

The coefficient of friction of dry surfaces will vary with the type of material used in the bearing and the mating shaft, the surface finish, and the degree of cleanliness at the respective contact surfaces. For absolutely clean surfaces, the values generally used for the coefficient of sliding friction are as shown in Table I.

Under moderate pressures, the frictional force is proportional to the normal load on the rubbing surfaces. It is assumed to be independent of the pressure per unit area of the surfaces. When the rubbing speed is of low velocity, the temperature of the surface is not generally affected and the coefficient of friction is approximately independent of the rubbing speed. At higher velocities it is found that the coefficient of friction decreases as the velocity increases.

3. Beneficial Effects of Lubricants on the Bearing Surfaces

Introduction of a lubricant between the two surfaces under operating conditions of imposed load and speed that cause an oil wedge to form, with the resultant separation of the respective surfaces by an established oil film, tends to reduce the frictional resistance to that equal to the relative shear of the lubricant itself, or its fluid friction.

Fluid lubrication of plain bearings will be governed to a major extent by the viscosity of the lubricant, the bearing clearance and length (or width) to diameter ratio, rubbing velocity of the shaft and applied unit load. To a minor extent it will be dependent on surface finish, principally whenever the region of boundary lubrication is approached. The wedge-shaped film which is formed between the journal and the bearing provides a hydrostatic pressure sufficient to float the journal and carry the load applied to it. Adhesion of the lubricant to the surfaces of the journal and the bearing make possible the formation of the desired oil wedge.

There are a number of ways of evaluating the performance of the oil film. One of these is through the use of the $\frac{ZN}{P}$ formula, and this will be the principal method used in the following practice. Another method which is preferred by some engineers is through the use of Sommerfeld variable. The latter is somewhat more complicated in its application because of the mathematics involved, but has some desirable features where more accurate design is required.

In full bearings where a continuous oil film is maintained, and where the bearing diameter is under 6 in.,

* Numbers refer to Bibliography at end of Recommended Practice.

the coefficient of friction may be calculated from the following Equation (2).

$$f = 473\left(\frac{ZN}{P}\right)\left(\frac{D}{C}\right) 10^{-10} + \Delta f \qquad (2)$$

where

Z = absolute viscosity, in centipoises, of the lubricant at the operating temperature of the bearing

N = speed of shaft in revolutions per minute

P = pressure in pounds per square inch of projected area of bearing

D = diameter of shaft in inches

C = clearance (diameter of the bearing minus the diameter of the shaft)

Δf = a correction factor determined by the ratio of length of the bearing to the diameter. This can be obtained from Figure 2.

In large diameter oil flooded precision bearings, the coefficient of friction may be calculated from the formula:

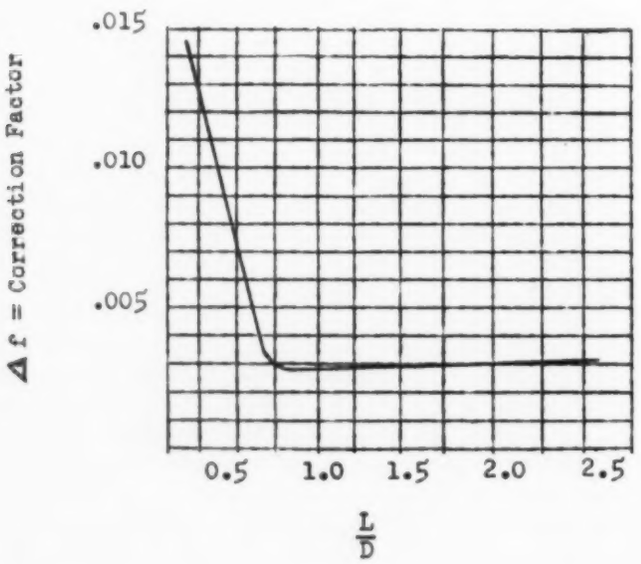
$$f = 0.001 + 0.00004\left(\frac{ZN}{P}\right) \qquad (3)$$

(The above Equation 3 is based on the standard clearance ratios now being used in the manufacture of these bearings.)

4. Principles of Good Design for Plain Bearings

1. The bearing surfaces are completely separated by a film of oil.
2. The friction of operation is the fluid friction in the oil film, and adequate thickness of film is essential.
3. During construction, proper clearance or space should be provided for a normal thickness of oil film.
4. The advance edge of a bearing surface must be rounded or chamfered off in order to permit a supporting film of oil to form.
5. The oil film forms most effectively upon a bearing surface whose advance edge is at right angles to the direction of motion.
6. An increase of speed increases the thickness of film, all other conditions remaining constant and clearance permitting.
7. An increase in the viscosity of the oil increases the thickness of film, all other conditions remaining constant and clearance permitting.
8. The larger the unbroken film of oil, the greater will be the average pressure-supporting capacity per unit area, other conditions remaining constant.
9. Every unnecessary oil groove or interruption in the continuity of the oil film reduces the supporting capacity of the film.
10. For every bearing condition, there is a film thickness corresponding to maximum lubrication efficiency.
11. Bearing surfaces can be machined to size by broaching, boring, reaming, and burnishing, dependent upon the bearing size and material. Reaming and burnishing of bearing inside diameters is most applicable to sizes up to two inches in diameter. Broaching of inside diameter bearing surfaces is generally confined to sizes up to four inches in diameter. Boring of bearing surfaces is effectively used over the entire bearing size range. This method of machining should employ sharp, single edge tools. Bearings finished in this manner show a definite tendency to not only produce dimensional accuracy, but also to retain the desired accuracy when placed in extended storage.

Figure 2 — The coefficient of friction is affected appreciably by the correction factor Δf, particularly when the ratio of bearing length to diameter is less than 0.75. ⑦



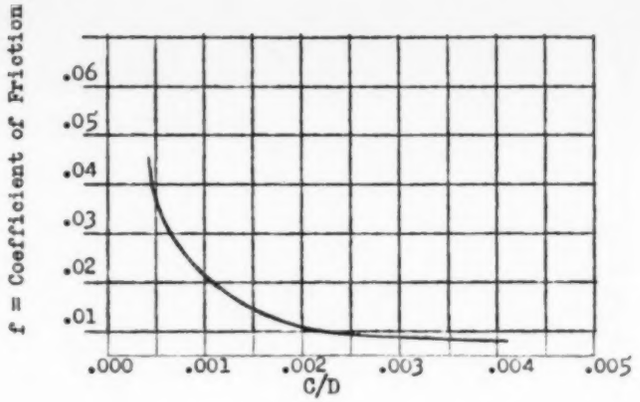


Figure 3 — A definite relationship exists between the coefficient of friction and the ratio of bearing clearance to shaft diameter. Data was taken on shafts under 6 in. in diameter. ⑦

From Equation 2 and Figure 2, it may be deduced that a rapid increase in friction occurs when the $\frac{L}{D}$ ratio becomes small. For precision bearings, this ratio should not be less than 0.5. For large diameter oil-flooded precision bearings this ratio should not be less than 0.6. For medium bearings the ratio should not be less than 1.0. For loose bearings, the ratio should not be

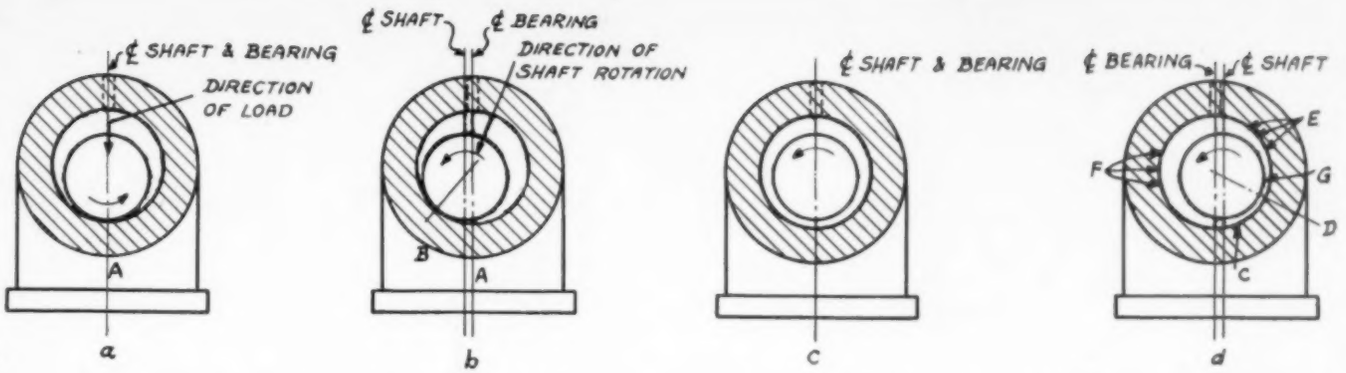


Figure 4 — Schematic illustration on buildup of oil film: "a" shows shaft at rest; "b" shows shaft starting to move and climb side of bearing; "c" shows that oil film has formed; "d" shows position of shaft after full speed has been reached.

less than 1.25, except in the case of phenolic resin water lubricated roll neck bearings where the ratios should not be less than 0.75.

It may be seen in Figure 3 that the coefficient of friction increases with small $\frac{C}{D}$ ratios. For bearing design the following minimum $\frac{C}{D}$ ratios will give satisfactory results:

1. For precision bearings, the minimum $\frac{C}{D}$ ratio will be 0.0005 for tri and white metals and self-lubricated powdered metal bearings; 0.0007 for copper lead, and 0.001 for aluminum bearings.
2. For large diameter oil flooded precision bearings, the minimum $\frac{C}{D}$ ratio will vary from 0.0015 to 0.001 for bearings running from 6 to 44 in. respectively. Under no circumstances will minimum clearance be less than 0.009 in. For surface speeds above 2000 fpm, higher clearances will be required.
3. For medium bearings, the minimum $\frac{C}{D}$ ratio will be 0.0015 for shafts up to 4 in., for shafts over 6 in. the minimum $\frac{C}{D}$ ratio will be 0.001. Between 4 and 6 in., clearance ratios will vary proportionately, and under no circumstances should minimum clearance be less than 0.004 in. For surface speeds above 2000 fpm higher clearances will be required.
4. For loose bearings, the minimum $\frac{C}{D}$ ratio will be 0.0025 for shafts up to 4 in. in diameter, but in no case should minimum clearance be less than 0.005. For shafts above 6 in. the minimum $\frac{C}{D}$ ratios will be 0.0015. Between 4 and 6 in., clearance ratios will vary proportionately.

5. Fundamentals of Oil Film Formation

The oil wedge is the fundamental basis of film formation, and the formation of the wedge and film as the result of rotating a shaft in a bearing is graphically described in Figure 4.

Figure 4a shows a shaft (journal) at rest in a bearing, the supporting film has been squeezed out by the imposed weight of the shaft, and actual metal to metal contact exists between the shaft and the bearing at "A." Under this condition, static friction is introduced as a resistance force which must be overcome before movement of the shaft can take place.

When slow movement of the shaft begins in the direction indicated by the curved arrow in Figure 4b, there is at first a tendency for the shaft to roll up the bearing to the left and assume the new line of contact with the bearing at "B," except that in this case it will be noted oil is present which separates the shaft and bearing surfaces, thereby facilitating the further movement of the shaft.

As the shaft speed or rubbing velocity increases, the lubricant in the clearance space which adheres to the more rapidly turning shaft is drawn into the narrowing wedge shaped space, thus gradually creating hydraulic pressure in the wedge. This pressure becomes greatest just preceding the tip, or thinnest portion of the wedge, and eventually lifts the shaft sufficiently off contact with the bearing, thus allowing the shaft to slip back to its original center position as shown in Figure 4c, but now definitely supported on a film of lubricant.

At top speed, the hydrauiic pressure in the wedge has increased so that it crowds the shaft to the other side of the bearing as shown in Figure 4d. The greatest pressure within the fluid film is now in the region of "C" in Figure 4d, while a line drawn through the centers of the shaft and bearing will extend in the direction of "D" (line of centers).

Within the area "F" of Figure 4d, on the descending side of the shaft, there is increasingly high film pressure, reaching a maximum in the region marked "C." A rapidly diminishing pressure exists in the area "G," and a minimum pressure in area "E."

As the varying pressure of the lubricant on the different portions of the shaft causes the shaft to change its position in the bearing, the pressures become

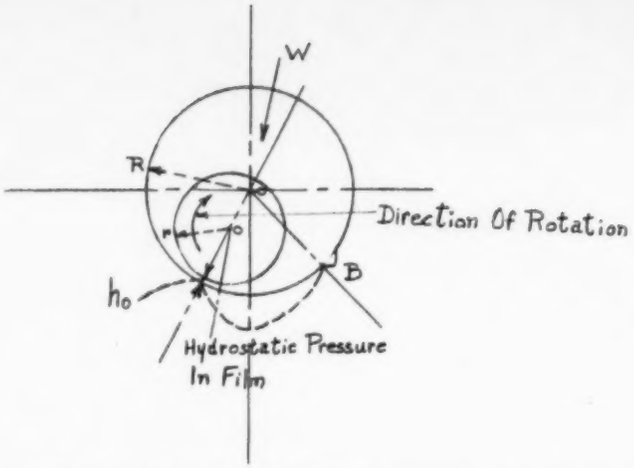


Figure 5 — The minimum film thickness sets the closest approach of the journal and the bearing.

readjusted until the bearing is in equilibrium. Many factors enter into this condition of equilibrium, including the amount of clearance between the shaft and the bearing, quantity of the lubricant supplied, load, speed, operating temperature and effectiveness of the lubricant distribution within the bearing, so that sufficient hydraulic pressure will be developed and maintained to float the shaft in the high pressure area of the bearing.

From this it can be seen that if the unit load of the bearing is very high or the rubbing velocity is of a low order, the lubricating film may not be established resulting in metal to metal contact and bearing wear, with a corresponding reduction in bearing service life.

In order to test lightly loaded or loose fit bearing design for the ability of the shaft to establish and maintain an adequate lubricating film with respect to the bearing, the following Formula 4 is generally employed. The expression includes a safety factor of 2.The formula has had extended usage in bearing design, but is limited to loose and medium fits plus light and medium loading ranges.

$$P = 15.5\sqrt[3]{V_m} \quad (4)$$

where

P = maximum unit bearing pressure in pounds per square inch

V_m = rubbing velocity in feet per minute

The minimum film thickness h_o determines the closest approach of the journal and bearing surfaces with complete lubrication present (Figure 5). The allowable closest approach depends on the degree of finish of the surfaces and on the rigidity of the journal and bearing structures.

The law governing the proper thickness of an oil film in a given bearing has not been clearly established in most cases, and should become a vital part of all machinery design. In modern machinery the average thickness of film varies from 0.0002 in. to 0.006 in.

The minimum thickness of the oil film developed between the journal and the bearing surfaces determines to a large extent the relative load capacity of the bearing itself. Of equal importance when making journal bearing calculations are the length to diameter ratio, clearance to diameter ratio, revolutions per minute, oil viscosity, rubbing velocity and in extreme cases where boundary lubrication is evidenced, the surface finish and coefficient of friction of the mating parts.

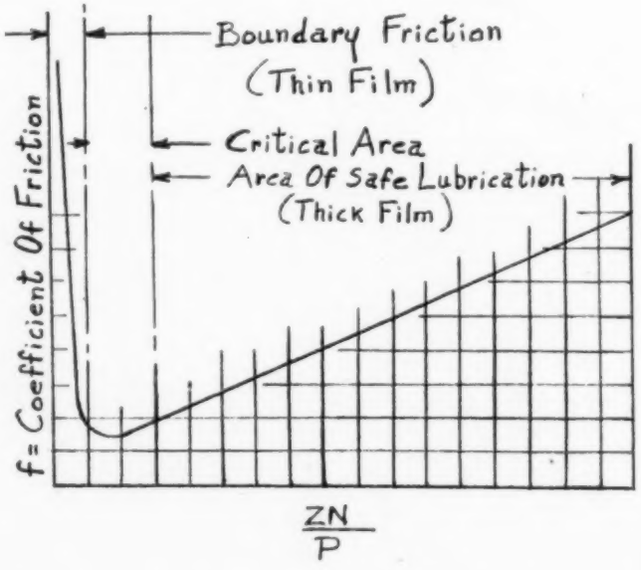
In practice, $h_o = 0.00075$ in. is generally used in electric motors and generators of medium speed with steel shafts in babbitted bearings; $h_o = 0.003$ to 0.005 in. for large steel shafts running at high speeds in babbitted bearings, (turbo-generators, fans, etc.) with pressure oil-supply for lubrication; $h_o = 0.0001$ to 0.0002 in. in automotive and diesel engines, with very fine finish of the surfaces. Note that "B" denotes location of oil groove.

When applying Formula 2 to a given bearing, the L/D (length to diameter) and D/C (diameter to clearance) ratios remain constant but $\frac{ZN}{P}\left(\frac{\text{viscosity} \times \text{speed}}{\text{pressure}}\right)$ will vary with the viscosity of the oil, the speed of the shaft and the unit pressure. If the $\frac{ZN}{P}$ values for a given bearing are established experimentally and plotted against the coefficient of friction, a graph of the general nature shown in Figure 6 will result. This is called the bearing characteristic.

It will be noted that for decreasing values of $\frac{ZN}{P}$ in the area of boundary friction, there is a sharp increase in the coefficient of friction. This is the result of irregularities in the bearing surface and the inability of the lubricant to entirely separate the surfaces.

The bearing characteristic is greatly influenced by surface roughness in the boundary area. Critical $\frac{ZN}{P}$

Figure 6 — The $\frac{ZN}{P}$ curve illustrates graphically the conditions under which the oil film will break down.



values are decreased with improvements in the quality of the surface finish.

This improvement in surface quality and consequent reduction in friction is observed in bearings that have been in use. Running in of the bearing accomplishes this refinement of the operating surface and is highly desirable.

6. Other Oil Film Design Methods

The design method already described using the $\frac{ZN}{P}$ variable is the one used in this recommended practice for bearing computations. Another approach to bearing design is through the use of the Sommerfeld variable. This is a more fundamental approach to the problem than the one previously used. The following description will cover briefly some of the fundamental work first developed and upon which present theoretical bearing design is based. This work covers the four fundamental items in which the bearing engineer is usually interested, namely, shaft load, shaft friction, minimum film thickness, and temperature rise.

The fundamental equation for oil film is a variation of Newton's law which states that at any point in a fluid, the shearing stress is proportional to the rate of shear, and when the velocity distribution is linear, this equation may be written:

$$\frac{S}{A} = \mu \times \frac{v}{h}$$

where S is the tangential load in lb
A = the area in sq inches
μ = the viscosity in reyns
v = the velocity in inches per sec
h = the height of the oil film in inches
This is a fundamental equation for frictional forces in the film in English units.

By expanding Newton's law to a full journal bearing, Petroff developed what is known as Petroff's equation which gives a value for the frictional torque. This equation is usually written as follows:

$$T = \pi^2 \left(\frac{D}{C}\right)\left(\frac{L}{D}\right) \quad \frac{\mu N D^3}{60} \qquad (5)$$

where T = the frictional torque, lb inches
D = diameter of shaft, inches
C = clearance (diameter of bearing minus diameter of shaft) inches
L = bearing length, inches
μ = viscosity, reyns
N = revolutions per minute

Where the bearing is lightly loaded, the film thickness may be considered uniform and the equation will reduce to the following:

$$f = 2\pi^2 \times \frac{D}{C} \times \mu \frac{N}{60P} \qquad (6)$$

where f = coefficient of friction. Equation 2 previously given as a working equation, is a refinement of Petroff's law [Eq. (5) and (6)] which takes into account the effect of bearing load on film thickness. Appreciable bearing loads, result in a variable film thickness which is contrary to one of the simplifying assumptions of Petroff's original equation. The $\frac{ZN}{P}$ variable of Equation 2 is a tool which enables a limited number of test results to be used for a fairly general analysis.

To take into account the effect of variable oil film thickness, Reynolds developed a differential equation which gave the variation in pressure over a bearing because of the change in film thickness and wedge effect of the oil film. Reynolds also integrated this equation for flat bearings of infinite width and for some partial bearings where the eccentricity was less than one-half the radial clearance. An infinitely wide bearing is a mathematical concept which enables the person solving the equation to assume that the side leakage of oil is a negligible amount compared with the oil flow around the bearing itself. As the length-diameter (or width-diameter) ratio of the bearing becomes less, this assumption becomes less valid, and the load which the oil film can support becomes less. For this reason, minimum values are given for the length-diameter ratios of bearings in this recommended practice.

Dr. A. Sommerfeld succeeded in finding mathematical solutions to Reynolds equation for all values of eccentricity and also extended the solution to half bearings and full bearings. His solution still assumes no side leakage or in other words a bearing of infinite width. Through the use of dimensionless analysis, sometimes called the π thereom, Sommerfeld was able to put his solutions in the form of equations which include a dimensionless factor called a Sommerfeld variable. By setting up curves based on this variable, problems can be solved relatively easily. The Sommerfeld variable is as follows:

$$S = \left(\frac{r}{c}\right)^2 \times \frac{\mu N}{P} \qquad (7)$$

where r = the radius, in.
c = radial clearance, in. (radius of bearing minus radius of shaft)

μ(viscosity) $= \frac{\text{lb sec}}{\text{in.}^2}$ reyns (Note: Z is also used in this practice for viscosity with units in centipoises.)

N = rpm (Note: Values of S in *this* practice are 60 times those when N is given in rps as used by many authorities. Use of rps also gives consistent units.)

$P = \frac{\text{lb}}{\text{in.}^2}$

The following illustrates the use of the procedure in solving bearing problems. Most problems on journal bearings are given with the speed in rpm and the load in lb per sq in. of projected area. Using these units, the operating equations with no end leakage are as follows:

Shaft load, psi

$$P = \frac{\mu N r^2}{c^2} \quad \frac{\pi}{60} C_p \qquad (8)$$

Shaft friction, psi

$$F = \frac{\mu N r}{c} \quad \frac{\pi}{60} C_f \qquad (9)$$

Least film thickness,

$$h_n = c\ (1\text{-}n) \qquad (10)$$

Temperature rise,

$$t = \frac{P}{112} C_t \qquad (11)$$

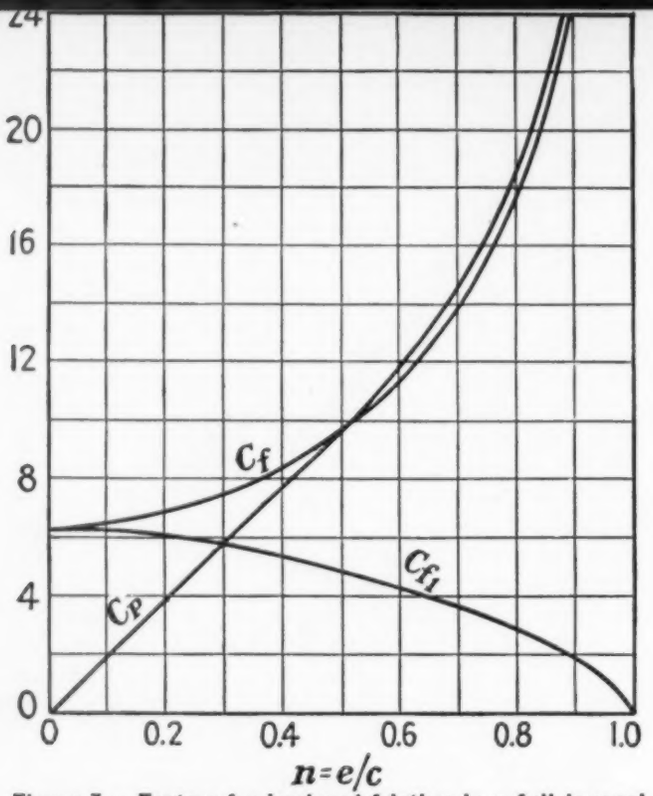


Figure 7 — Factors for load and friction in a full journal bearing using oil of uniform viscosity and without side leakage. (From Norton's "Lubrication" — McGraw-Hill Book Co.)

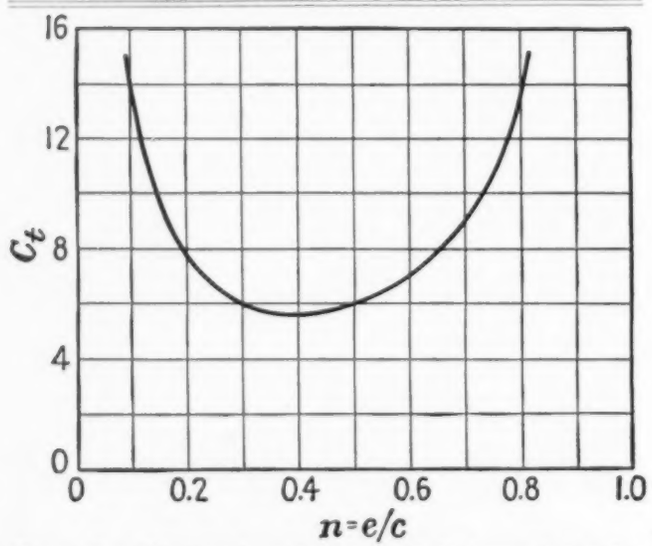


Figure 8 — Temperature factor of full journal bearing using oil of uniform viscosity and without side leakage. (From Norton's "Lubrication" — McGraw-Hill Book Co.)

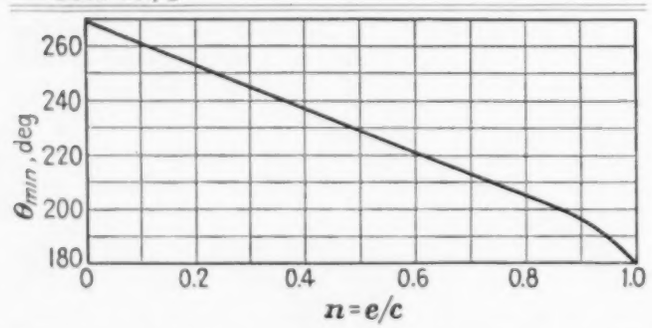


Figure 9 — Location of minimum pressure in full journal bearing using oil of uniform viscosity and without side leakage. (From Norton's "Lubrication" — McGraw-Hill Book Co.)

The terminology is as previously given, and n equals the ratio of the eccentricity to the radial clearance ($n=e/c$). This ratio is also called the attitude. The attitude angle is the angle between the bearing load resultant and line of centers. This angle is 90 degrees for full journal bearing of infinite length (no leakage) and less than 90 degrees for a bearing with end leakage. The attitude equals approximately the cosine of the attitude angle and from this relationship, the attitude angle can be found. Numerical values of dimensionless C_p, C_f, and C_{f_1} are given in Figure 7 as functions of n. Factors for C_t are given in Figure 8. The position of minimum pressure is given in Figure 9 where the angle θ to point of minimum oil film pressure (measured from the line of centers in direction of rotation) is plotted against the ratio of the eccentricity to clearance. The line of centers is the line joining the center of the bearing and the center of the shaft when the bearing is operating at eccentricity e.

The following example illustrates the use of these charts.

A full journal bearing operates with the following data: L=8 in., r=2 in., W=7550 lb, N=200 rpm, c=0.002 in., h_n=0.0008 in. Find the mean viscosity of the oil to realize the above conditions and the amount of power and heat loss.

By Eq. (10) $0.0008=0.002\ (1-n)$

$n=0.6$

From Figure 7 $C_p=12$

$C_f=11.5$

By Eq. (8)

$$\frac{7550}{8\times 2\times 2}=\frac{\mu\times 200\times 2^2}{0.002^2}\ \frac{\pi}{60}\times 12$$

$$\mu=\frac{1.9}{10^6}\ \text{reyns}$$

By Eq. (9)

$$F=\frac{1.9}{10^6}\times\frac{200\times 2}{0.002}\times\frac{\pi}{60}\times 11.5=0.228\ \text{psi}$$

$$H=F\ 2\ r\ L\ \frac{2\ \pi\ rN}{60}=\text{Total heat energy/sec}$$

$$=0.228\times 2\times 2\times 8\times 2\times\pi\times 2\times 200\div 60$$
$$=306\ \text{in. lb/sec}$$

$$H=\frac{306}{9336}=0.033\ \text{Btu/sec}$$

Problems for full journal bearings may also be quickly solved through the use of Figure 10 which gives the Sommerfeld variable as the abscissa. The curves of this chart have been derived from the operating equations for the full journal bearing transformed algebraically into convenient forms for plotting.

To illustrate the use of the chart, the previous example will be solved finding the temperature rise, coefficient of friction, and position of minimum pressure. Using the previous data:

$$\frac{h_n}{c}=\frac{0.0008}{0.002}=0.4$$

Then going to the Sommerfeld chart for $\frac{h_n}{c}$ which

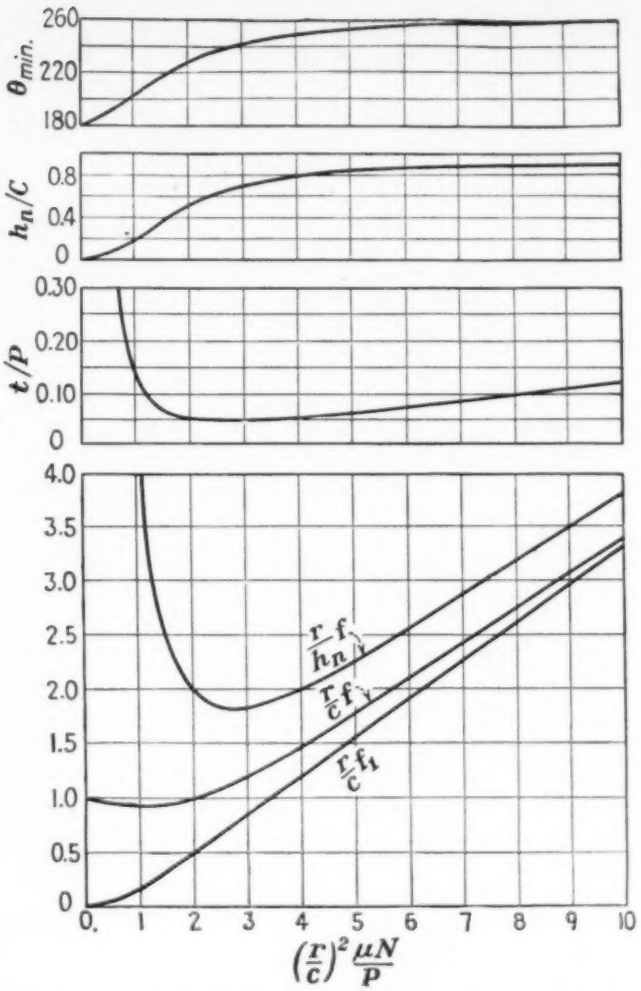


Figure 10 — Sommerfeld chart is made up for a full journal bearing using oil of uniform viscosity and without side leakage. (From Norton's "Lubrication" — McGraw-Hill Book Co.)

equals 0.4, the Sommerfeld variable from scaling off the abscissa is 1.6. Substituting in the equation:

$$\frac{r^2}{c^2}\,\frac{\mu N}{P}=1.6$$

$$\mu=1.6\times\frac{236}{200}\times\left(\frac{0.002}{2}\right)^2=\frac{1.9}{10^6}\text{ reyns}$$

From Figure 10, the variables may be simply taken from the chart using an abscissa value of 1.6 which gives the following values:

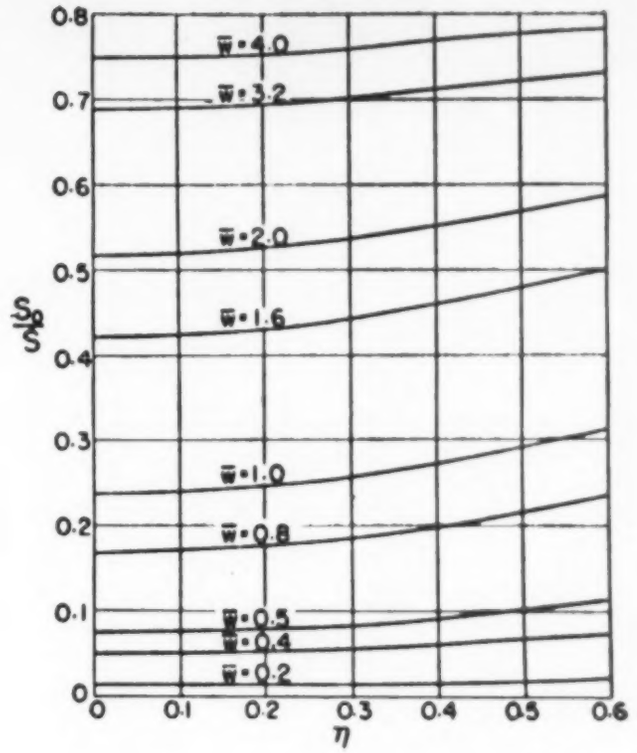


Figure 12 — Relative load carrying capacities of flooded journal bearings of finite width. As can be seen from Figure 11, two bearings running under identical conditions but with different lengths will have different attitudes. Note also change in attitude in Figure 11 between infinite length bearing and finite length bearing. (Courtesy Gulf Research and Development Co.)

$$f\frac{r}{c}=0.95$$

$$f=0.00095$$

$$F=P\,f=0.227\text{ psi}$$

$$H=2rLF\,\frac{2\pi rN}{60}=305\text{ in. lb/sec}$$

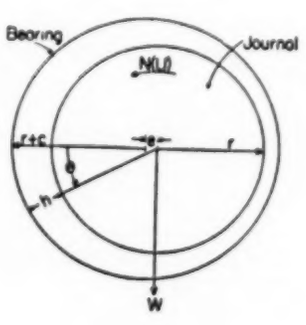
$$\frac{t}{P}=0.065$$

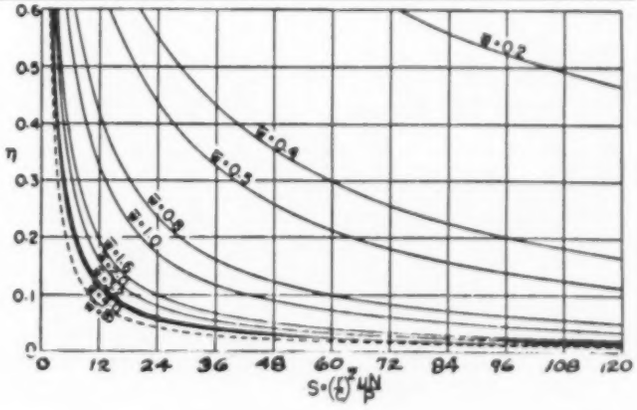
$$t=15F$$

$$\theta\text{ min}=220\text{ degrees}$$

From the above example, the simplicity of the application of this method is apparent and as a result the Sommerfeld variable is becoming more prevalent. It is

Figure 11 (on right) — Chart shows variation of journal eccentricity n with the Sommerfeld variable for flooded journal bearings of finite width. Terminology is given in sketch on left. (Courtesy Gulf Research and Development Co.)





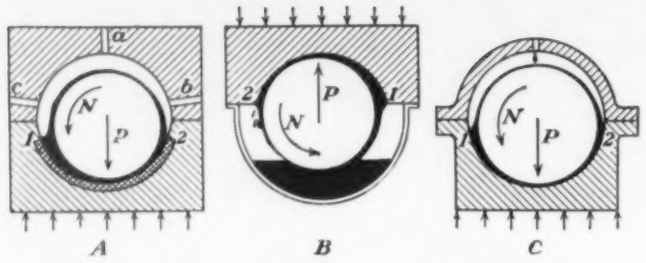
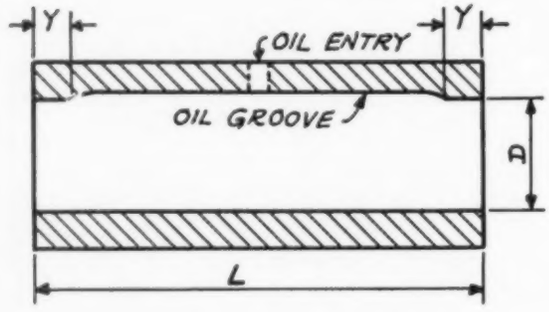


Figure 13 — Three examples of partial bearings are shown with the clearances exaggerated. ④

A			B		
PRECISION	MEDIUM	LOOSE	PRECISION	MEDIUM	LOOSE
0.06D	0.08D	0.10D	0.5A	0.5A	0.5A

Figure 14 — Recommended dimensions for oil grooving. This recommendation does not apply to large diameter flood lubricated oil film bearings.



Y			
PRECISION	LARGE DIAM. FLOODED PRECIS.	MEDIUM	LOOSE
0.06D 1/4" MIN.	0.05 L	0.08D 3/8" MIN.	0.10D 1/2" MIN.

Figure 15 — Recommended dimensions for oil sealing.

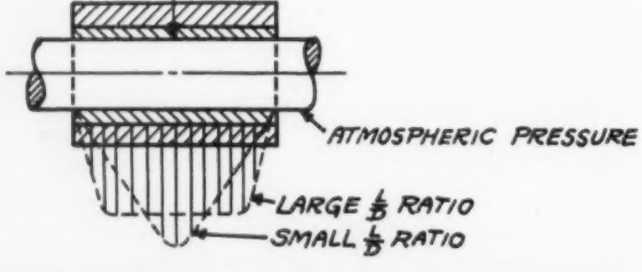


Figure 16—Broken lines indicate longitudinal oil film pressure distribution.

still true, however, that the friction versus $\frac{ZN}{P}$ diagram is the standard method of representing the results of friction tests. The curves of Figure 10 hold for any full journal bearing if the assumptions behind the equations are accepted or true.

One of the big assumptions of the previous development is that there is no side leakage present. Corrections for this may be made through the use of Figure 11. This chart shows the relationship of the eccentricity ratio n (sometimes called attitude) to the Sommerfeld number which is plotted as the abscissa, w is the ratio of the bearing width to the bearing diameter and $w = \infty$ is the value given in the classical theory assuming no side leakage. The other ratios for w in the chart shows the effect of leakage on the attitude. Knowing the new attitude, the values for the equations may be approximated from Figures 7, 8, and 9.

Because of end leakage, the oil film cannot carry the load given by the usual theory. The reduction in load carrying capacity for various finite widths is given in Figure 12, where the ordinate or Y axis gives the ratio of the load carrying capacity of a bearing of finite width to the load carrying capacity of the same bearing of infinite width, or in other words, with no end leakage. This curve is plotted against the eccentricity ratio (or attitude) for various width-diameter ratios. This shows why a groove in the loaded zone of the bearing is so harmful, since the groove reduces the width-diameter ratio and the load capacity of the film.

A partial journal bearing is one in which the effective film does not completely surround the shaft. In such bearings the film usually extends over an arc of less than 180 degrees. A partial bearing having clearance is one whose surface has a slightly larger radius than the shaft. A bearing having its bearing surface machined to the same radius as the shaft, i.e., having zero clearance, is a fitted bearing.

The operating equations [corresponding to Eq. (8) (9) (10) (11)] have the same form as those for the full journal bearing. The only difference is that in the mathematical solutions, the limits of integration are different. As a result, the operating equations instead of being dependent on the eccentricity ratio n alone, are dependent on the eccentricity ratio; the angle of bearing arc covered by the partial bearing, and the angle between line of centers to the beginning of the partial bearing measured in the direction of rotation. For solving partial bearing problems, graphs are plotted from tabulated values in a manner similar to that previously described for full journal bearings, and such charts are available in standard texts. ⑨⑫

Partial bearings are common in some mill equipment and Figure 13 shows three examples of partial bearings. In Figure 13-a, the bearing presses upward on the shaft and the oil is supplied at convenient points such as a, b or c from which adhesion to the shaft carries it to the inlet space at 1. The clearance of the cap is greater than that of the effective bearing surface and careful chamfering connects the two surfaces. Rotation of the journal builds up pressures in the field between points 1 and 2. When pressure lubrication is used, the oil may be admitted at b and drawn off at c. Although more oil may be used than necessary, the excess oil acts as a

cooling agent. In Figure 13-b the bearing presses down on the shaft and the oil is supplied by a bath which wets the under side of the shaft. This case is typical of railroad car wheels.

It is also possible for a full journal bearing to operate as a partial bearing if the oil is not furnished in sufficient quantities to fill the clearance space or if the feed pressure is not sufficient. Such an example is illustrated in Figure 13-c. In all partial bearings, it is assumed that the oil enters and leaves the effective clearance space at atmospheric pressure and normally no pressure feed device is needed such as usually recommended on full journal bearings. Partial bearings are also most advantageously employed when the load is nearly vertical. The inlet and outlet may have abrupt edges or may be joined to the cap by smooth transition surfaces. In the event a cap is provided, its function is to keep out dirt, to prevent oil from being thrown off, or to hold a journal in case of unusual changes in the direction of the load.

7. Fundamentals of Oil Grooving

The primary purpose of providing oil grooving is to direct the distribution of the lubricant within a given bearing, in such a manner as to promote the formation and maintenance of a separating and supporting film between the journal and the bearing. Any groove which performs this simple function is correct, and conversely any groove which induces the breakdown of the separating film and conducts the lubricant away from the pressure area is incorrect. This basic principle offers a positive guide to correct grooving practice.

Oil grooves that terminate close to the ends of the bearing increase end leakage. It is, therefore, advisable to terminate the grooves at a predetermined distance from the end of the bearing, based upon specific engineering design and certain qualified minimums. It has been found from past experience that for the very small bearings under 1 in. in length, no grooving would be needed except on applications of light loads or oscillatory motion where the pressure does not build up appreciably. A range of minimums, starting with $\frac{1}{4}$ in. for the smaller, $\frac{3}{8}$ in. for the medium size and $\frac{1}{2}$ in. for the larger bearing will suffice. Feathering the end of the groove to zero also assists materially in effecting better lubricant distribution.

Oil grooving, and the distribution of lubricant within a bearing are vitally important features of its design. Correct grooving and correct lubrication will insure the success of any bearing, providing the other elements involved are also correct. Improper grooving and lubrication will guarantee an unsuccessful bearing regardless of how much of the design is otherwise correct. See Figures 14 and 15.

Special attention should be exercised when chamfering oil-groove edges to ensure that all advance edges of a bearing are rounded, this thereby permits the oil wedge effect to take place giving an adequate oil film for sustaining the radial loads imposed on the bearing proper. A good rule to apply in this case is to perform the chamfering of all oil grooves after all other tooling of the bearing has been completed.

When designing a bearing to support a given load, consideration must be given to the effects of oil film pressure distribution as reflected by the $\frac{L}{D}$ ratio in order

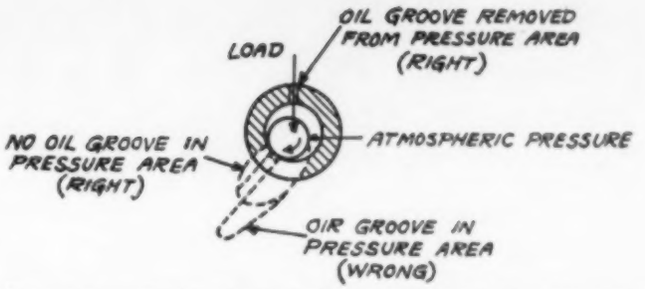

OIL GROOVE REMOVED FROM PRESSURE AREA (RIGHT)
LOAD
NO OIL GROOVE IN PRESSURE AREA (RIGHT)
ATMOSPHERIC PRESSURE
OIR GROOVE IN PRESSURE AREA (WRONG)

Figure 17 — Broken lines indicate radial oil film pressure distribution for the cases with and without an oil groove in the pressure area.

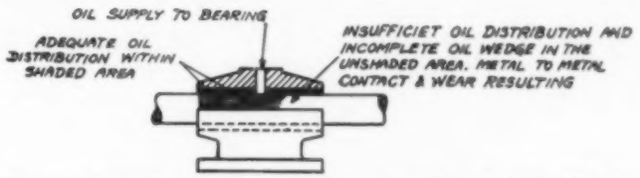

OIL SUPPLY TO BEARING
ADEQUATE OIL DISTRIBUTION WITHIN SHADED AREA
INSUFFICIET OIL DISTRIBUTION AND INCOMPLETE OIL WEDGE IN THE UNSHADED AREA. METAL TO METAL CONTACT & WEAR RESULTING

Figure 18 — Sketch shows unequal oil film distribution in a bearing without a suitable groove.

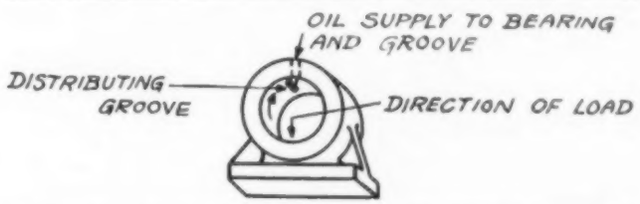


Figure 19 — A single oil groove as illustrated will ordinarily give proper lubrication in a full rounded bearing.

that a bearing of adequate size can be selected for the duties intended. The relationship which grooving plays in the oil film pressure distribution of a bearing is a vital one, and as such must be included in proper bearing design.

In Figure 16 the broken lines indicate the oil film pressure distribution over a given bearing length. It may be clearly seen what relative effect the $\frac{L}{D}$ ratio has on the resultant pressure curve of the bearing and why a thorough knowledge of this phenomena can assist in better bearing design. When an oil groove is located in the pressure area of a bearing as shown in Figure 17, it is noted that the pressure pattern is broken up and produces a greater maximum pressure, which contributes to failure of the oil film and increased end leakage.

In a bearing without suitable distributing grooves, the tendency is for the lubricant to be carried in the direction of the shaft rotation along the path of least resistance into the pressure area. This action does not usually give the lubricant an opportunity to spread equally in both directions along the length of the bearing as illustrated in Figure 18. The result may be an incomplete wedge at one end of the bearing. The hydraulic pressure developed in this partial wedge acts on only a portion of the shaft and is not sufficient to lift the journal completely out of contact with the bearing, causing undue wear or total destruction of the bearing.

Proper lubricant distribution in a full round bearing as shown by Figure 19, where the load is applied at the

bottom, is generally obtained by a longitudinal groove at the top into which the lubricant supply hole is drilled. This groove extends axially from the point of introduction of the lubricant supply towards each end of the bearing. It should be terminated far enough back from the end of the bearing to insure against excessive end leakage. The corners of the groove should be round to prevent scraping off lubricant which adheres to the shaft, and to permit free entrance of the lubricant into the clearance space to form the necessary wedge.

With larger shaft sizes, in combination with a limited supply of lubricant, the circumferential distance between a distributing groove located on the top center and a loaded area towards the bottom center may be too great. The lubricant is spread so thin that an adequate supply of lubricant for wedge and film formation is lacking.

An increase in the lubricant supply is usually an effective remedy, but improved performance will be obtained if the distributing groove and feeder groove are provided as shown in Figure 20. The distributing groove is moved in the direction of shaft rotation towards the point of load application, and is supplied through a feeder groove opening into the lubricant supply hole.

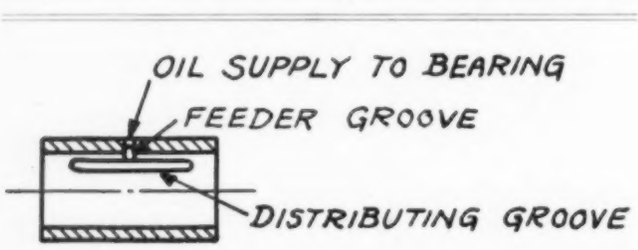


Figure 20 — Sketch shows oil distribution groove and feeder in a large diameter bearing.

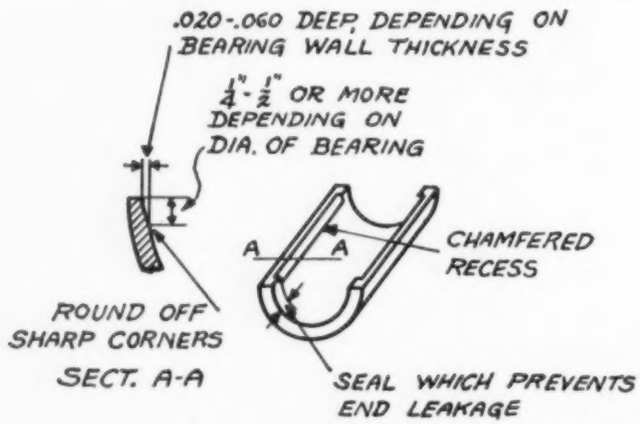

.020-.060 DEEP, DEPENDING ON BEARING WALL THICKNESS
¼" - ½" OR MORE DEPENDING ON DIA. OF BEARING
A
A
CHAMFERED RECESS
ROUND OFF SHARP CORNERS
SECT. A-A
SEAL WHICH PREVENTS END LEAKAGE

Figure 21 — An effective distributing groove in a split bearing can be obtained with simple chamfers.

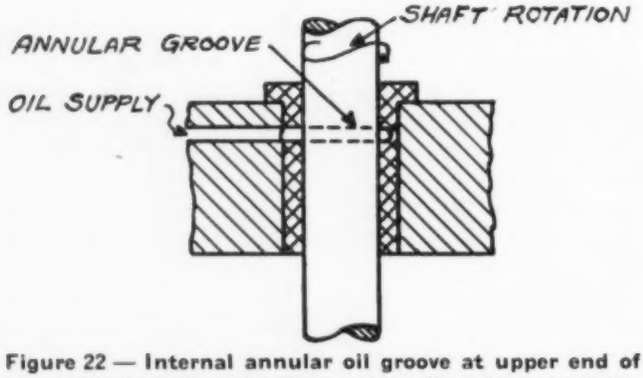


Figure 22 — Internal annular oil groove at upper end of vertical bearing distributes oil uniformly around the bearing.

In a split bearing, an effective distributing groove is obtained by a chamfered recess, as shown in Figure 21. At the parting faces the depth of this recess may be 0.020 to 0.060 in., or more, depending on the bearing wall thickness, and it may be tapered out to zero in a distance of ¼ - ½ in., or more, depending on the diameter of the bearing. For a heavily loaded low speed bearing (approximately 50 rpm or under), an additional distributing groove or lubricant reservoir may be provided very close but not located within the beginning of the pressure area. A full volume of lubricant at this vital point is thus assured. This auxiliary groove should be terminated approximately the same distance from the ends of the bearing as established by the chamfered recess.

The proximity of an auxiliary groove of this character to the area of maximum pressure places special importance on determining from a study of the forces acting on the journal, the exact location of the pressure area. The surface of the journal must pass over the groove before it reaches the maximum pressure.

A good rule to apply is that any bearing made without distributing grooves should have the lubricant introduced where the clearance is greatest, that is, in a region where there is no journal pressure against the bearing surface. When a distributing groove is correctly located in a low pressure area, the position of the lubricant supply hole is of a lesser importance, providing the supply hole is higher than the distributing groove and the two are connected by an adequate feeder groove. The feeder groove must be applied in the direction of the journal rotation, never against it.

Most vertical bearings serve merely as guides, holding a shaft in a definite fixed position and carry little pressure. The formation and maintenance of a lubricating film is defeated mainly by leakage from the lower end of the bearing. Because of these inherent conditions, such bearings frequently may be lubricated without the aid of grooving.

If more positive lubrication is required, an internal annular groove at the upper end of the bearing and in line with the lubricant supply hole as shown in Figure 22 is usually sufficient. This groove acts as a reservoir from which the lubricant carries down through the clearance space.

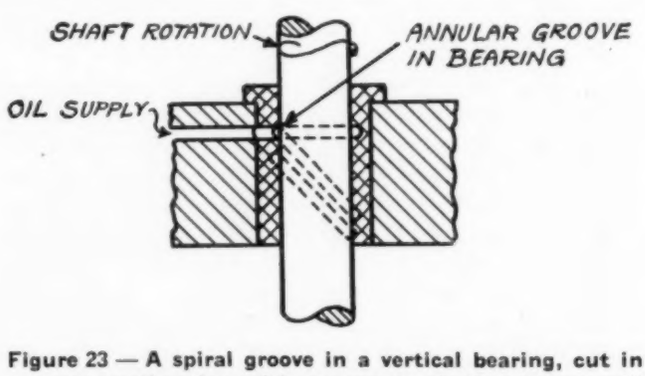


Figure 23 — A spiral groove in a vertical bearing, cut in proper direction with respect to shaft rotation, will minimize leakage at bottom of bearing.

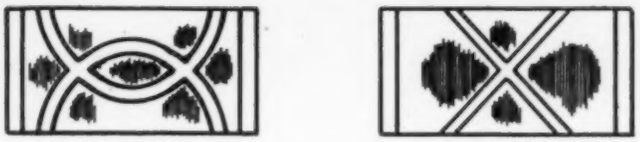


Figure 24 — Grooving in the pressure area of a bearing relieves the hydraulic pressure in the oil film adjacent to the grooves with resultant damage to the bearing.

Leakage from the lower end may be minimized by cutting a spiral groove in such a direction that the rotating shaft will lightly pump the lubricant upwards as shown in Figure 23.

8. Incorrect Oil Grooving

Complicated and elaborate grooves in a bearing surface are seldom necessary or useful. When the pressure area is crossed, or criss-crossed with grooves, similar to those shown in Figure 24, the load carrying capacity is materially reduced.

Whenever the area of pressure is cut by grooves, the lubricant which is drawn into the wedge by the revolving shaft immediately takes the path of least resistance, into the grooves and away from the pressure area. This easy exit of the lubricant prevents the building up of hydraulic pressure in the film, and also prevents floating of the journal with the resultant increased bearing wear.

9. Grooving Comparisons — Oil and Grease

In comparison with lubricating oils, grease may not be a readily mobile lubricant. In view of this essential difference in flow characteristics, the grease must be applied to the bearing surface close to the area of pressure, by grooves which will insure full length distribution. Grease grooves may be made slightly wider than those used in oil lubrication to assist in adhesion of the grease, due to greater contact area, on the rotating shaft. Wider grooves permit the shaft a longer contact time period with the grease supply, and consequently a greater quantity will be picked up and carried along.

Corners of the grooves must be well rounded off, even more so than where oil lubrication is employed, to prevent the grease which is adhering to the shaft from being scraped off. The pattern of grease grooves, in the low pressure area, can be fairly elaborate, but extra precaution should be exercised to eliminate any grooves in the high pressure area and to keep this localized critical bearing surface unbroken. Where contamination is found to be an important factor in field service, it has been found advisable to provide annular grooves near the outer ends of the bearing, which when loaded with grease offer a dam effect preventing the entry of the contaminants.

Grease as a lubricant for plain bearings of certain types has advantages over oil, including:

1. Bearings for slow speed shafts (under 50 rpm) and very heavy loads, which factors would prevent the formation and maintenance of an oil film. Under these conditions, and in combination with high temperature operation, grease is particularly useful.
2. Bearings subjected to intermittent operation where an oil would not remain in place.
3. In bearings where it is impossible to provide a uniform and economical supply of oil, and where the infrequency and unreliability of oil application by hand would result in periods of non-lubrication.

10. Calculation of Bearing Areas

The design of journal bearings requires the satisfaction of two requirements: first, the area of the bearing metal must be such that it has adequate strength to resist the applied load; and second, the viscosity, clearance and surface finish must be such that an oil film is built up which will carry the load. Although often so considered in design, the bearing load is not applied uniformly over the bearing area, and maximum intensities of as much as twice the average are commonly encountered. Keeping this variation in mind, it is relatively simple to compute the bearing metal area. The computation of the oil film is a much more difficult subject. Some of the fundamentals to be kept in mind are the following. Heat is generated in a journal bearing because of shearing in the oil film and this heat produces a rise in temperature. The temperature rise increases heat dissipation and also decreases the viscosity of the lubricant. In the region of stable lubrication, a decrease in viscosity decreases the amount of heat which is generated and the bearing temperature rises to a point where the rate of heat generation is balanced by the rate of heat dissipation. For this reason, the ability of the bearing to dissipate heat is as important as the hydro-dynamics of the oil film. On the other hand, in the unstable region, the rate of heat generation increases more rapidly than the rate of heat dissipation. Then as the temperature rises, the viscosity of the oil becomes less as well as its ability to support the load and eventually the oil film breaks down. This then sets up the two primary criteria in bearing design, namely, that the bearing must operate in the region of stable lubrication and second, the operating temperature shall not exceed some limiting value. Both the Sommerfeld variable and the $\frac{ZN}{P}$ curves can be used to show whether the bearing will operate in the stable region.

The following example illustrates how a bearing area is determined by the $\frac{ZN}{P}$ method. Data given by Tables II and III are used in the calculations. Care must be taken to design bearing for actual load and load direction. Load direction is not necessarily vertical or related to split on bearing.

The projected area of a bearing, shall be at least that given by the formula:

$$A = \frac{\left(\frac{ZN}{P}\ \text{Value}\right) F_s\, W}{ZN} \qquad (12)$$

where

$A = D \times L$ = Projected area of bearing in square inches

F_s = Factor safety

W = Total load in lb

Z = Absolute viscosity in centipoises (At operating temperature)
N = Shaft speed in rpm

Example:

A guide roll with a total load of 2400 lb is supported in two bearings and rotates at 400 rpm. The bearings are lubricated by a circulating oil system with a 300 SSU., at 100 F, mineral oil. This oil has an absolute viscosity at 130 F of 31 centipoises. An operating temperature, maximum 130 F, is assumed. Determine the bearing length. This bearing will fall in the medium bearing classification.

$\frac{ZN}{P}$ Value = 30 from Table II

W = Total load on each bearing = 1200 pounds
Z = Absolute viscosity at 130 F = 31
N = 400 rpm
F_s = Factor safety from Table III = 1.5

$$A = \frac{30 \times 1.5 \times 1200}{31 \times 400} = \frac{54000}{12400} = 4.35 \text{ sq in.} = L \times D$$

Assuming an L/D ratio of 1.5, then

$$D = \frac{A}{1.5\ D} \text{ or } D^2 = \frac{A}{1.5} \text{ and } D = \sqrt{\frac{A}{1.5}}$$

$$D = \sqrt{\frac{4.35}{1.5}} = \sqrt{2.90} = 1.703 = \text{Say } 1.75$$

From this, a shaft diameter of 1.75(1¾ in.) is chosen.

$$\text{Bearing length} = \frac{A}{D} \text{ or } L = \frac{4.35}{1.75} = 2.48 \text{ Say } 2.50 \text{ or } (2\tfrac{1}{2} \text{ in.})$$

$$\text{The actual L/D ratio} = \frac{2.50}{1.75} = 1.43,$$

which is satisfactory

TABLE II

CALCULATION OF BEARING AREA

	$\frac{ZN}{P}$
Precision bearings	20
Large diameter oil flooded precision bearings	20
Medium bearings	30
Loose bearings	50 - 100

TABLE III

When operating conditions include shock load and/or intermittent (stop - start)	F_s = Factor safety
Precision bearings	1.0
Large diameter oil flooded precision bearings	1.0
Medium bearings	1.5
Loose bearings	2.0

11. Bearing Types — Mathematical Evaluation

A conclusion is drawn from a recent mathematical study of the various bearing types regarding their relative load-carrying capacity. In this study, the speed of the journal was denoted by "journal rpm," and that of the rotating load by "load rpm." The journal rpm and load rpm will be taken to have the same algebraic sign if they represent rotations in the same direction, and opposite signs if they represent rotations in opposite directions. Then the load-carrying capacity of the bearing for different speeds of journal and load is given by: Load-carrying capacity = K (2 load rpm — journal rpm), where it is understood the absolute value of the expression in the parentheses will be taken. The factor K for a given bearing depends on length, diameter, clearance, minimum oil film thickness, and on the viscosity of the oil.

Several types of bearings are considered including various combinations of load and journal speeds of rotation. In each case, where one of these speeds is to be held constant (other than zero), a basic speed of 1000 rpm will be selected for comparative purposes. The other speed will sometimes be varied, as will be shown in the following examples:

Unidirectional Load (*Figure 25a*) — A bearing with a load of constant direction, such as a turbine bearing, a railroad car journal, etc., using the basic formula would offer the following:

Load speed = 0
Journal speed = 1000
Load carrying capacity = LCC

LCC = K (2 × 0 — 1000) = 1000 K The minus indicates only the fact that the minimum oil film is leading in phase angle and for general work can be ignored.

Rotating — Direction Load with Rotating Shaft (*Figure 25b*)

LCC = K (2 × 1000 —1000) = 1000 K

Rotating — Direction Load with No Shaft Rotation (*Figure 25c*)

LCC = K (2 × 1000 —0) = 2000 K

Critical Speed (*Figure 25d*) — When (2 load rpm — journal rpm) is zero, the LCC = 0. That is, when the load is rotating in the same direction as the journal and at one-half the journal speed, then even though the magnitude of the load is very small, the oil film will not develop, and metal to metal contact will take place.

An interesting example of a bearing operation at the critical combination of load and journal speed is the excitation of shaft whip by the action of the oil film in journal bearings.

Floating Bushings (*Figures 25e and 25f*) — Although floating bushings have been utilized for several applications with the assumption that improved load capacity

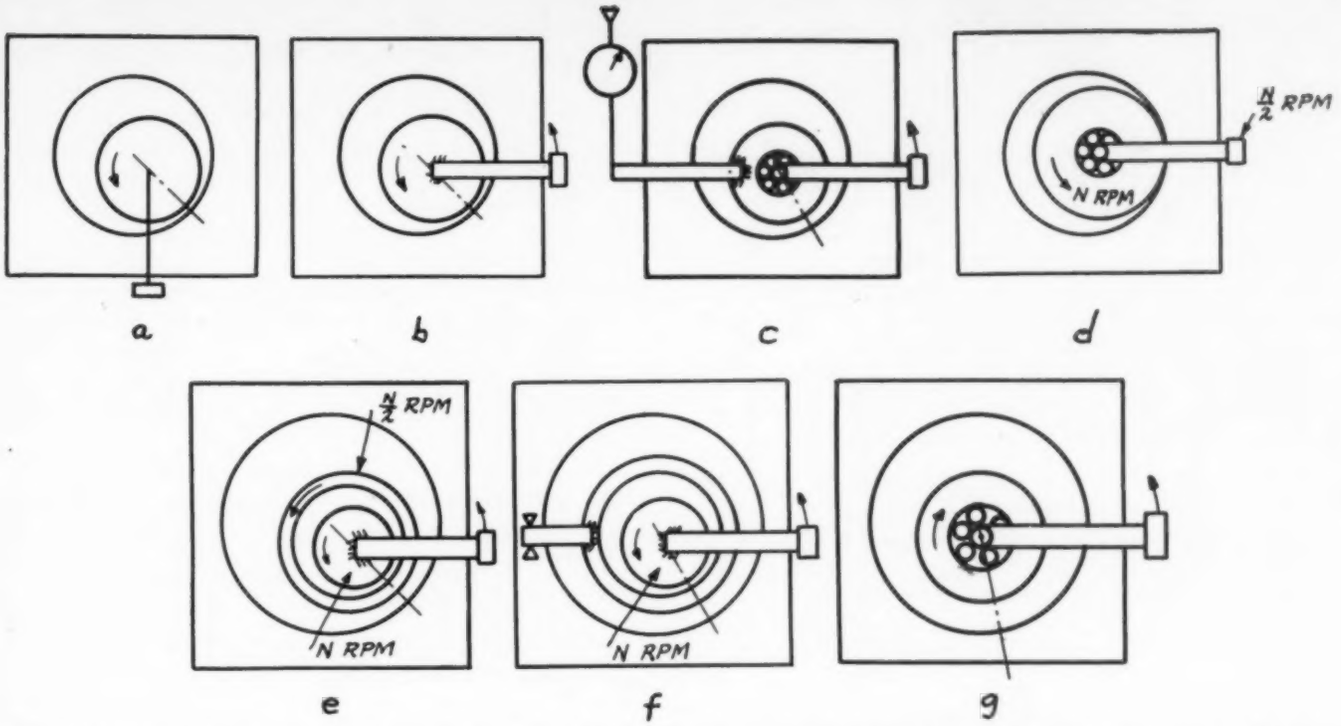


Figure 25 — Rotational direction affects load capacities appreciably. Sketches give cases and load capacities as follows: "a" Unidirectional load-capacity 1K; "b" Rotating-direction load with rotating shaft-capacity 1K; "c" Rotating-direction load with no shaft rotation-capacity 2K; "d" Critical speed-zero load capacity; "e" Floating bushing-inner capacity 0.5K, outer capacity 1.5K; "f" Non-revolving floating bushing-inner capacity 1K, outer capacity 2K; "g" High capacity bearing-capacity 3K. (M)

resulted, the use of the formula indicates that this is a false premise. Assume the floating bushing is turning at half the 1000 rpm journal speed and further, the load weight is fixed to the revolving shaft. Then, for the inner oil film between the shaft and the bushing, the relative load speed is 500 rpm and the relative surface speed is 500 rpm. Therefore $(2 \times 500 - 500) = 500$ K.

$$LCC = K\ (2 \times 500 - 500) = 500\ K$$

But for the outer oil film between the stationary support and the bushing, the relative load speed is the full 1000 rpm, while the relative surface speed remains at 500 rpm. This gives: $LCC = K\ (2 \times 1000 - 500) = 1500$ K. In other words, the outer oil film has three times the load capacity of the inner bearing. If an ordinary bearing (Figure 25b) was used, the capacity would be 1000 K, so the use of a floating bushing can reduce the load carried by a bearing.

Study of the two oil films will show that the optimum result is obtained when the floating bushing is restrained from rotation. The rotation may be prevented by an arm or pin, as in Figure 25*f*. Now, the inner oil film becomes exactly the same as covered in Figure 25*b* which has a load capacity of 1000 K. Thus, the capacity of 500 K is double. Similarly, the nonrotating floating bushing has an outside oil film which becomes identical to that covered in Figure 25*c*. Such a bearing has a 2000 K capacity, or a 33 per cent increase over the 1500 K capacity when the bushing is rotated at half speed.

Practice often has proved that a well designed plain bearing has the same load-carrying ability as a floating bushing, which thus verifies the mathematical conclusion.

High-Capacity Bearing (Figure 25g) — If the load speed is positive, and the journal speed negative (that is, if the two rotations are in opposite directions) an interesting case develops. Assuming a load speed of + 1000 rpm and a journal speed of —1000 rpm, the formula gives: $LCC = K\ [2 \times 1000 - (-1000)] = 3000$ K. Study of the formula shows that no critical speed occurs when the load and journal rotate in opposite directions. At given load speeds, the bearing capacity continually increases with the journal speeds.

A summary of the load capacities of bearings, based upon the mathematical theory, is given in Table IV.

TABLE IV (M)
SUMMARY — BEARING LOAD CAPACITIES

	Relative load-carrying capacity
1. Unidirectional load (turbine bearing, gear load bearing, etc.)	1
2. Rotating — direction load with rotating shaft (centrifugal bearing test machine bearing loaded by an eccentric weight)	1
3. Rotating — direction load with no shaft rotation (support for measuring friction torque in a bearing; outer oil film of a nonrotating floating bushing)	2
4. Critical speed (when the journal rpm is twice the frequency of load; special case is of oil film whirl at twice resonant frequency of shaft whip)	0
5. Floating bushing at half speed —	
Inner oil film	½
Outer oil film	1½
6. Nonrotating floating bushing —	
Inner oil film (same as type shown in Figure 25b)	1
Outer oil film (same as type shown in Figure 25c)	2
7. High capacity bearing (load and journal revolving in opposite directions)	3

12. Metal Bearing Material Properties

To perform satisfactorily as a bearing material the metal must have certain essential characteristics both with respect to the lubricant used and the type of metal employed in the journal. For many years in the past, metals used in bearings were judged by a relatively few mechanical properties such as compressive strength, elongation and hardness. From such meager information, it was difficult to properly evaluate the limitations of the respective bearing material for the various applications under consideration. It is now recognized, based upon several independent studies in recent years, that any metal or alloy can function as a bearing provided it possesses the following properties:

1. *Fatigue resistance* — Fatigue resistance of both solid and porous bronze or cast iron, composition or carbon-graphite bearings are of so high an order as to be of little concern. On the other hand, white metal alloys, copper-base alloys, aluminum alloys, etc., when subjected to bearing fatigue are found to be quite critical in this respect. In fact, this property may often be the controlling factor in the use of a particular alloy. Fatigue resistance is of paramount importance for bearings which are subjected to alternating loads, such as connecting rods and main bearings of internal combustion engines.

2. *Non-scoring characteristics* — During the period of starting up or where boundary lubrication is encountered, metal to metal contact is known to occur. The score resistance or anti-seizure characteristics of the bearing metal under these conditions will be judged on the ability to minimize the damage to the journal. It is believed that the excellent non-scoring properties of the tin, lead and cadmium base alloys is due to a thin non-metallic film which forms very rapidly under these adverse operating conditions.

3. *Compressive strength* — Compressive strength is the ability of the metal to withstand the imposed load without extrusion or cracking. In a bearing with a unidirectional load, this requirement is quite important. As the inherent compressive strength becomes less, it is necessary to employ thinner bearing linings to prevent excess extrusion.

4. *Conformability* — The ability of the bearing alloy to conform, due to its plasticity, to any surface irregularities of the journal and thereby permit a more uniform distribution of load within the bearing proper is known as its conformability.

5. *Embeddability* — This is a measure of the ability of the bearing material to permit dirt or foreign matter which is carried into the clearance space to embed in the bearing surface. White metal alloys, because of their greater embeddability characteristics, are quite often selected at the expense of fatigue life where dirty conditions prevail. The harder bearing materials which have poor embeddability retain the dirt on the surface, thereby permitting an abrasive action to take place with scoring or grooving of the shaft resulting.

6. *Corrosion resistance* — Bearing materials should possess good resistance to the corrosive action of oil deterioration products resulting from oil oxidation when subjected to high operating temperatures. Tin-base babbitt has been found to be highly resistant, and as such is resorted to when other materials prove to be unsatisfactory. Incorporating inhibitors in the oil as a means of obtaining greater stability toward the formation of these corrosive organic acids is also resorted to as a means of control.

7. *Bonding characteristics* — A prerequisite of any bearing metal when bonded to a metal back is to have good bonding or adherence qualities. This characteristic is especially critical on bearings subjected to heavy-duty loading conditions. Modern casting techniques have developed to a point where metallurgical bond between the bearing back and bearing material is relatively easy and economical to obtain.

Designs specifying assumed mechanical bonding aids, such as dovetailing, etc., are in general but a compromise for inadequate preparation of the contacting metal surfaces and are found to be more of a hinderance than an aid to bearing quality. Straight bores for casting bearing material can be effectively cleaned prior to casting, thus resulting in better bonding of the bearing material to its back. Typical examples of the effectiveness of this recommended practice include heavy duty automotive, diesel and high speed oil film bearing installations. The elimination of dovetails, etc., reduce bearing cost by effecting a reduction in machining time and bearing metal requirements.

Properties of many bearing materials are given in Table V, VI and VII. Bearing metals should be selected so that the average normal bearing stress over the projected area does not exceed the values given in Table VIII.

Both the tin and lead-base babbitts possess qualities which are conducive to satisfactory service operations where employed in the steel industry for the various field applications of plain bearings. Tin-base babbitt is generally preferred for the more critical operations due to its superior bondability, heat conductivity, fatigue resistance to shock loads and somewhat higher strength at operating temperatures. On the other hand, lead-base babbitt usage has been expanded throughout the industry to a point where a considerable savings in tin has been forthcoming. With the inauguration of the tin conservation program, lead-base babbitt has been substituted for tin-base babbitt on most of the less critical operations where severe pounding or higher speeds and temperatures are not a factor. A considerable amount of lead-base babbitt with arsenic or silver added has also been utilized for the same general type of coverage.

The main object in adding arsenic or silver to lead-base alloys is to raise the strength at elevated temperatures. This can be accomplished with the addition of a relatively small percentage of either arsenic or silver. The arsenic tends to lower the ductility somewhat, especially in the presence of tin. The low tin content in turn, and also the arsenic, tend to lower the bondability. Extreme caution must be exercised to prevent mixing other scrap of high tin content with the arsenic babbitt scrap, as the arsenic alloy developed thereby becomes brittle if the tin is much over 2 per cent. Considerable increase in the rate of oil oxidation has been noted where arsenic lead-base babbitt bearings have been employed, especially where elevated temperatures are

TABLE V (17)

PROPERTIES OF PURE METALS, RELATING TO THEIR BEARING PROPERTIES (1)

Bearing material	Affinity for steel (2)	Electrode potential volts (3)	Brinell hardness	Thermal conductivity Cal/cm²/°C/sec	Young's modulus, psi	Coefficient of thermal expansion per °C
Pb	Low	+0.12	3	0.08	2,600,000	29
Sn	High	+0.14	5	0.16	6–8,000,000	0.000022–46
Ag	Low	—0.80	25	0.97	10,000,000	0.000019
Cd	Intermediate	+0.40	21	0.22	10,000,000	0.000030
Al	High	+1.70	16	0.52	10,000,000	0.000024
Cu	High	—0.34	30	0.92	16,000,000	0.000016
Zn	High	+0.76	30–35	0.27	13,000,000	0.000028
Mg	Low	+2.40	30	0.37	6,200,000	0.000026
Fe	High	+0.44	70	0.19	30,000,000	0.000012
Ni	High	+0.23	64	0.14	30,000,000	0.000014

(1) The materials are arranged in the order of their bearing properties, with the best materials at the top.
(2) As estimated from the ease with which they wet clean steel when molten.
(3) A high positive voltage indicates reactivity, a high negative voltage inertness.

THERMAL COEFFICIENT OF EXPANSION IN DEGREE CENTIGRADE

Tin-base babbitt	0.000022—0.000024
Lead-base babbitt	0.000024—0.000028
Bronze	0.000018
Steel	0.000012

TABLE VI

COMPOSITIONS AND PHYSICAL PROPERTIES OF TIN-BASE AND LEAD-BASE BEARING ALLOYS

ASTM alloy grade	Specific gravity	Composition, per cent				Compression tests				Brinell hardness		Melting point		Temp of complete liquefaction		Proper pouring temp	
						Yield point, psi		Ultimate strength, psi									
		Cu	Sn	Sb	Pb	20 C	100 C	20 C	100 C	20 C	100 C	F	C	F	C	F	C
1	7.34	4.56	90.9	4.52	None	4400	2650	12,850	6950	17.0	8.0	433	223	700	371	825	441
2	7.39	3.1	89.2	7.4	0.03	6100	3000	14,900	8700	24.5	12.0	466	241	669	354	795	424
3	7.46	8.3	83.4	8.2	0.03	6600	3150	17,600	9900	27.0	14.5	464	240	792	422	915	491
4	7.52	3.0	75.0	11.6	10.2	5550	2150	16,150	6900	24.5	12.0	363	184	583	306	710	377
5	7.75	2.0	65.5	14.1	18.2	5050	2150	15,050	6750	22.5	10.0	358	181	565	296	690	366
6	9.33	1.5	19.8	14.6	63.7	3800	2050	14,550	8050	21.0	10.5	358	181	531	277	655	346
7	9.73	0.11	10.0	14.5	75.0	3550	1600	15,650	6150	22.5	10.5	464	240	514	268	640	338
8	10.04	0.14	5.2	14.9	79.4	3400	1750	15,600	6150	20.0	9.5	459	237	522	272	645	341
10	10.07	0.12	2.05	15.7	82.0	3350	1850	15,450	5750	17.5	9.0	468	242	507	264	630	332
11	10.28	0.19	0.09	14.8	84.7	3050	1400	12,800	5100	15.0	7.0	471	244	504	262	630	332
12	10.67	0.12	0.11	9.9	89.4	2800	1250	12,900	5100	14.5	6.5	473	245	498	259	625	329
15	10.05	0.5	1.0	15.0	82.5	.....	.....	.....	.....	21.0	13.0	479	248	538	281	662	350
16	9.88	0.5	10.0	12.5	77.0	.....	.....	.....	.....	27.5	13.6	471	244	495	257	620	327
19	10.50	.....	5.0	9.0	86.0	.....	.....	15,600	6100	17.7	8.0	462	239	495	257	620	327

TABLE VII

PHYSICAL AND MECHANICAL PROPERTIES OF ALUMINUM-BASE BEARING ALLOYS

Alloy grade	Specific gravity	Composition, per cent						Yield strength, psi	Tensile strength, psi	Elongation, per cent	Brinell hardness	Endurance limit, psi	Thermal conductivity Cal/cm²/°C/sec	Coefficient of thermal expansion per °C
		Cu	Sn	Ni	Si	Mg	Cd							
750-T5 (Heat treated)	2.88	1.0	6.5	1.0	.....	.....	.....	10,000	22,000	12	45	9000	0.44	0.0000243
750-T101 (Cold worked)	.....	1.0	6.5	1.0	.....	.....	.....	16,000	23,000	8	50	.....	.....	.....
XA-750-T6 (Heat treated)	2.83	1.0	6.5	0.5	2.5	.....	.....	10,000	22,000	10	45	9500	0.40	0.0000238
XA-750-T91 (Cold worked)	.....	1.0	6.5	0.5	2.5	.....	.....	17,000	23,000	7	50	.....	.....	.....
XB-750-T5 (Heat treated)	2.88	2.0	6.5	1.2	.....	0.8	.....	20,000	30,000	5	70	.....	0.43	0.0000239
XB80S-H12 (Cold worked sheet)	.....	1.0	6.5	0.5	1.5	.....	.....	23,000	25,000	6	50	.....	.....	.....
Al-Cd-Si (As cast)	.....	.....	.....	.....	4.0	.....	1.2	7,500	20,000	10	40	.....	.....	.....

TABLE VIII [18]

BEARING LOAD RATINGS (PSI) BASED ON PROJECTED AREA

	Psi*
Precision bearings	
1. High tin-base babbitt	1000—1800
2. High lead-base babbitt	1000—1600
3. High lead bronze	1800—3000
4. Aluminum bronze	3000—4000
5. Conventional brass	1600—2500
6. Aluminum	2000—4000
7. Cadmium — nickel	1500—2500
8. Composition	2000—3000
9. Plated tin (thin wall)	2500—4000
10. Copper — lead (thin wall)	1500—2500
11. Plated grid	2000—4000
Large diameter oil-flooded precision bearings	
1. High tin-base babbitt	2000—2500
2. High lead-base babbitt	1000—1500
3. Aluminum	3000—4000
4. Cadmium — nickel	2500—3000
Medium bearings	
1. High tin-base babbitt	600—1000
2. High lead-base babbitt	500—1000
3. High lead bronze	800—1800
4. Aluminum bronze	2500—3000
5. Conventional brass	800—1600
6. Composition	2500—3000
Loose bearings	
1. High tin-base babbitt	200— 600
2. High lead-base babbitt	200— 500
3. High lead bronze	800—1000
4. Aluminum bronze	1500—2000
5. Conventional brass	500—1000
6. Composition	2500—3000

*The lower values will be used for the higher temperature applications.

encountered along with higher speeds. Field experience will, to a large extent, dictate the respective limitations of the general usage of the arsenic lead-base babbitt compositions.

Silver also increases the strength of the lead-base babbitt at elevated temperatures while showing no appreciable reduction in ductility. Unlike arsenic, silver has no adverse effect on the bondability. The silver alloy is quite stable, and can be remelted repeatedly without changing its composition; it is not sensitive to tin contamination during the remelt cycle.

Table IX tabulates some typical bearing design practices as recommended by one authority. In addition to bearing loads, recommendations are given for viscosity, ZN/P, clearance and length-diameter ratios. These values are in general in accord with the remainder of this recommended practice, although there are a few cases which are exeeptions to the general rule.

13. Recommendations for the Pouring and Casting of Bearings

1. Preparing to cast: Clean bearing shell thoroughly of all dirt, rust, oil or any other foreign substance.
2. Do not mix metal or alloys of unknown metallurgy.
3. Heat metal slowly. This is absolutely necessary in handling lead base metal with a "tin content," because the tin will "sweat out" before the bars "break," and coming in contact with the hot ladle bottom, will be lost before the body of metal can take it up.
4. Have the mandrel and casting, or shell, made hot so that the metal will reach every interstice of anchorage and thereby make solid bearings.
5. Use a good luting mixture to pack joints in order to prevent the molten metal from escaping.
6. Where possible, place bearings in a vertical position for pouring. In all cases provide "waste head" large enough to permit the metal to stay molten therein until after the bearing proper has solidified. This will prevent air bubbles or shrinkage in the bearing shell.
7. Have pot large enough to make a continuous pour. An interval of only five seconds will make a fault in the bond which results in lessening the service life of the bearing. Repeated casting applications on the same bearing permit segregation in the cross section of the bearing reducing the bearing capacity correspondingly.
8. During the melting of the bearing metal, oxidation and waste can be minimized by covering the molten metal bath with powdered charcoal.
9. Thoroughly "tin" crank pin and motor bearings. Straight tin base metal should be used and as tin base metal will heat quickly if lubrication is lacking in service operation, it must have a chance to radiate. If bushing or brass is not tinned, a film of oil generally forms between the bushing or casing and the babbitt metal. This allows heat pockets to develop as the result of the insulating effect of the oil film with the babbitt roughing up or running out of the heat zone. Where no insulating film is present, the heat is conducted away rapidly enough to prevent damage to the bearing.
10. Stir metal thoroughly by driving ladle to bottom so as to agitate the entire pot content.
11. In order to secure the best results, always cool the newly poured bearing quickly "from the bottom up" by applying cold water to it. This assists materially in maintaining the hardness of the metal in the bearing.
12. Obtain from the supplier the correct pouring temperature for the bearing metal in question.
13. A good rule to follow is heat slowly, stir thoroughly and pour quickly.

Some satisfactory babbitt compositions are given in Table X and Table XI.

14. ASTM Conversion Tables for Kinematic and Saybolt Universal Viscosities

When Saybolt universal viscosity equivalents are to be determined for kinematic viscosities the multipliers listed in the following equations[18] may be used:

Saybolt universal viscosity at 100 F in seconds = kinematic viscosity at 100 F in centistokes × 4.620 (13)

TABLE IX

TYPICAL BEARING-DESIGN PRACTICE

Machinery	Bearing	Maximum load intensity, psi	Suitable oil viscosity, centipoise	Minimum permissible $\frac{ZN}{P}$	Recommended $\frac{C}{D}$	Recommended $\frac{L}{D}$
Automobile engines	Main	800† to 1700‡	7-8	15	.....	0.8 to 1.8
	Crankpin	1500*† to 3500‡	.....	10	.....	0.7 to 1.4
	Wrist pin	2300*† to 5000‡	.....	8	.....	1.5 to 2.2
Gas and oil engines, 4-cycle	Main	700*† to 1200‡	.....	20	0.0010	0.6 to 2.0
	Crankpin	1400*† to 1800‡	20-65	10	>0.0010	0.6 to 1.5
	Wrist pin	1800*† to 2200‡	.....	5	>0.0010	1.5 to 2.0
Gas and oil engines, 2-cycle	Main	500*† to 800‡	.....	25	0.0010	0.6 to 2.0
	Crankpin	1000*† to 1500‡	20-65	12	>0.0010	0.6 to 1.5
	Wrist pin	1200*† to 1800‡	.....	10	>0.0010	1.5 to 2.0
Stationary slow-speed steam engines	Main	400	60	20	>0.0010	1.0 to 2.0
	Crankpin	1500	80	6	>0.0010	0.9 to 1.3
	Wrist pin	1800	60	5	>0.0010	1.2 to 1.5
Stationary high-speed steam engines	Main	250	15	25	>0.0010	1.5 to 3.0
	Crankpin	600	30	6	>0.0010	0.9 to 1.5
	Wrist pin	1800	25	5	>0.0010	1.3 to 1.7
Reciprocating pumps and compressors	Main	250*	.....	30	0.0010	1.0 to 2.2
	Crankpin	600*	30-80	20	>0.0010	0.9 to 1.7
	Wrist pin	1000*†	.....	10	>0.0010	1.5 to 2.0
Steam locomotives	Driving axle	550	100	30	0.0010	1.6 to 1.8
	Crankpin	2000	40	5	>0.0010	0.7 to 1.1
	Wrist pin	4000	30	5	>0.0010	0.8 to 1.3
Railway cars	Axle	500	100	50	0.0010	1.8 to 2.0
Steam turbines	Main	100* to 275‡	2-16	100	0.0010	1.0 to 2.0
Generators, motors, centrifugal pumps	Rotor	100* to 200*	25	200	0.0013	1.0 to 2.0
Gyroscope	Rotor	850	30	55	0.0013	.....
Transmission shafting	Light, fixed	25*	.....	100	0.0010	2.0 to 3.0
	Self-aligning	100*	25-60	30	0.0010	2.5 to 4.0
	Heavy	100*	.....	30	0.0010	2.0 to 3.0
Machine tools	Main	300	40	1	0.0010	1.0 to 4.0
Punching and shearing machines	Main	4000*	100	.....	0.0010	1.0 to 2.0
	Crankpin	8000*	100	.....	0.0010	1.0 to 2.0
Rolling mills	Main	3000	50	10	0.0015	1.1 to 1.5

*Ring or drop oiler.
†Splash or scraper lubrication.
‡Force-feed lubrication.

TABLE X

SAE SPECIFICATIONS FOR BABBITT METALS

SAE No.	Per cent Sn	Per cent Pb	Per cent Sb	Per cent Cu	Per cent As
10	90 min	0.35 max	4—5	4—5	0.10 max
11	86 min	0.35 max	6—7½	5—6½	0.10 max
12	87¾ min	0.35 max	7—8½	2¼—3¾	0.10 max
13	4½—5½	86	9¼—10¾	0.50 max	0.60 max
14	9¼—10¾	76	14—16	0.50 max	0.60 max
15	0.9—1.25	balance	14½—15½	0.50 max	0.80—1.10

TABLE XI

SOME TYPICAL STEEL MILL BABBITT COMPOSITIONS

Type of babbitt	Composition, per cent						Brinell hardness	
	Sn	Sb	Cu	Pb	As	Ag	At room temperature	At 212 F
Tin base	89	7.5	3.5	.....	.....	.....	18.2	10.0
	84	10	6	.....	.....	.....	19.1	10.6
Lead base	10	15	0.5	74.5	.....	.....		
	5	15	.....	80	.....	.....	15.1	8.4
Lead base with arsenic	1	15	0.5	82.5	1	.....		
	0.75	12.5		83.75	3	.....	16.5	10.8
Lead base with silver	3	10	0.2	84.2	.....	2.6	14.7	10.5

Saybolt universal viscosity at 210 F in seconds = kinematic viscosity at 210 F in centistokes × 4.6524 (14)

Kinematic viscosity at 100 F in centistokes = Saybolt universal viscosity at 100 F in seconds × 0.2165 (15)

Kinematic viscosity at 210 F in centistokes = Saybolt universal viscosity at 210 F in seconds × 0.2150 (16)

Conversions at any other temperature "t" F may be calculated by multiplying the equivalent Saybolt universal viscosity at 100 F by 1 + (t —100) 0.000064 (17)

The slight differences in constants in these equations at 100 F and 210 F are due to the temperature expansion of the oil. The difference in viscosity between 100 and 210 F is of a much higher order.

When converting from kinematic viscosity to absolute viscosity, multiply the specific gravity of the oil at the given temperature by the kinematic viscosity at the given temperature in centistokes, which gives a resultant expressed in terms of centipoises.

In the English system of units as far as lubrication work is concerned, the viscosity would be a pound second divided by a square inch $\frac{\text{lb sec}}{\text{in.}^2}$. This unit is called the reyn, after Sir Osborne Reynolds. In the metric, or European system of units, viscosity would be a dyne second, divided by a centimeter square, $\frac{\text{dyne sec}}{\text{cm}^2}$. This unit is known as the poise, named after Poiseuille, the French physicist. The poise is rather a large unit of viscosity, so that the centipoise is frequently used, being 0.01 poise. Thus one poise equals 100 centipoises. In converting from one system of units to the other, the conversion factor used is as follows:

Number of reyns equals 1.45×10^{-5} the number of poises, or (18)

Number of reyns equals 1.45×10^{-7} the number of centipoises (19)

In converting to the absolute viscosity in English units, or reyns, when the resultant absolute viscosity in centiposes has been determined, (assuming a resultant of 18.7 centipoises), the following example is given:

$$\text{Number of reyns} = 1.45 \times 10^{-7} \times 18.7$$
$$= 27.12 \times 10^{-7}$$
$$= 0.000002712$$

15. Viscosity — Temperature Relationship

The change in viscosity of an oil varies with different types and their method of refining. For example, naphthenic oils thin out more rapidly than paraffine base oils, as the temperature rises. Modern methods of refining have enhanced the finished oil to such an extent as to preclude the identification of the source of the oil based upon the viscosity index (V.I.). However, within reasonable limits, the arbitrary system of comparison established by Dean and Davis, wherein Pennsylvania oils were given a rating of 100 and Texas or California oils were given a rating of 0, is still valuable to express the relative change of viscosity with temperature. In all bearing calculations this phenomena must be taken into consideration in order to establish the desired minimum oil film thickness at the operating temperature of the bearing. A viscosity index of 50 indicates a point midway on the scale. At the present time, lubricating oils both synthetic and special treated petroleum base, have been found which will exceed 100 on the scale.

In determining the accurate viscosity index (V.I.) of an oil, the following equation is generally used:

$$\text{V.I.} = \frac{\text{L} - \text{U}}{\text{L} - \text{H}} \times 100 \qquad (20)$$

where

U is the viscosity of the oil being checked at 100 F, L is the viscosity at 100 F of 0 V.I. (the coastal oil), which has the same viscosity at 210 F, as the oil whose V.I. is being determined. H is the viscosity at 100 F of an oil of 100 V.I. (Pennsylvania) which has the same viscosity at 210 F as the oil whose V.I. is being determined.

The values for L and H in Saybolt universal seconds viscosity are given in the ASTM tables. In these tables, the top line represents an oil with 0 viscosity index. The lower line represents an oil with 100 viscosity index. The dashed line in between represents the unknown oil. The viscosity index, therefore, is a measure of how closely the unknown oil approaches the 100 V.I. oil. The completed tabulation is found in the ASTM viscosity index tables (D567).

Figure 26 gives a chart prepared by Dean and Davis which in nomograph form enables estimating of the viscosity index by drawing a straight line through any two viscosities at different temperatures, and extrapolating to the viscosity index figures as shown. For example, an oil having a viscosity of 232 at 100 F, and of 47 at 210 F will have a viscosity index of about 80 as shown by the above dotted line.

16. Bushing Mounting Suggestions

A common error made when mounting bushings is that of failure to take into consideration the thermal expansion properties of the metals employed. Figure 27 illustrates a bronze bushing mounted in a cast iron housing with a pressed fit. As all bearing alloys have a temperature coefficient of expansion higher than that of cast iron and steel, and as the bearing is directly subject to the friction of the mating journal, it follows that the bearing is at a higher temperature than the cast iron housing and will, in this case, tend to expand appreciably inward when in operation due to the lack of space to permit normal outward expansion. For this reason, care should be exercised during the mounting phase to provide just enough pressure to prevent looseness during operation.

Due caution must be exercised when driving in bushings to prevent excess inward pressures being exerted on the finished bore, even after final fitting. This practice results in overheating of the bearing with accelerated wear of the mating parts. An optimum fit should be provided commensurate with known expansion rates of the given metals involved.

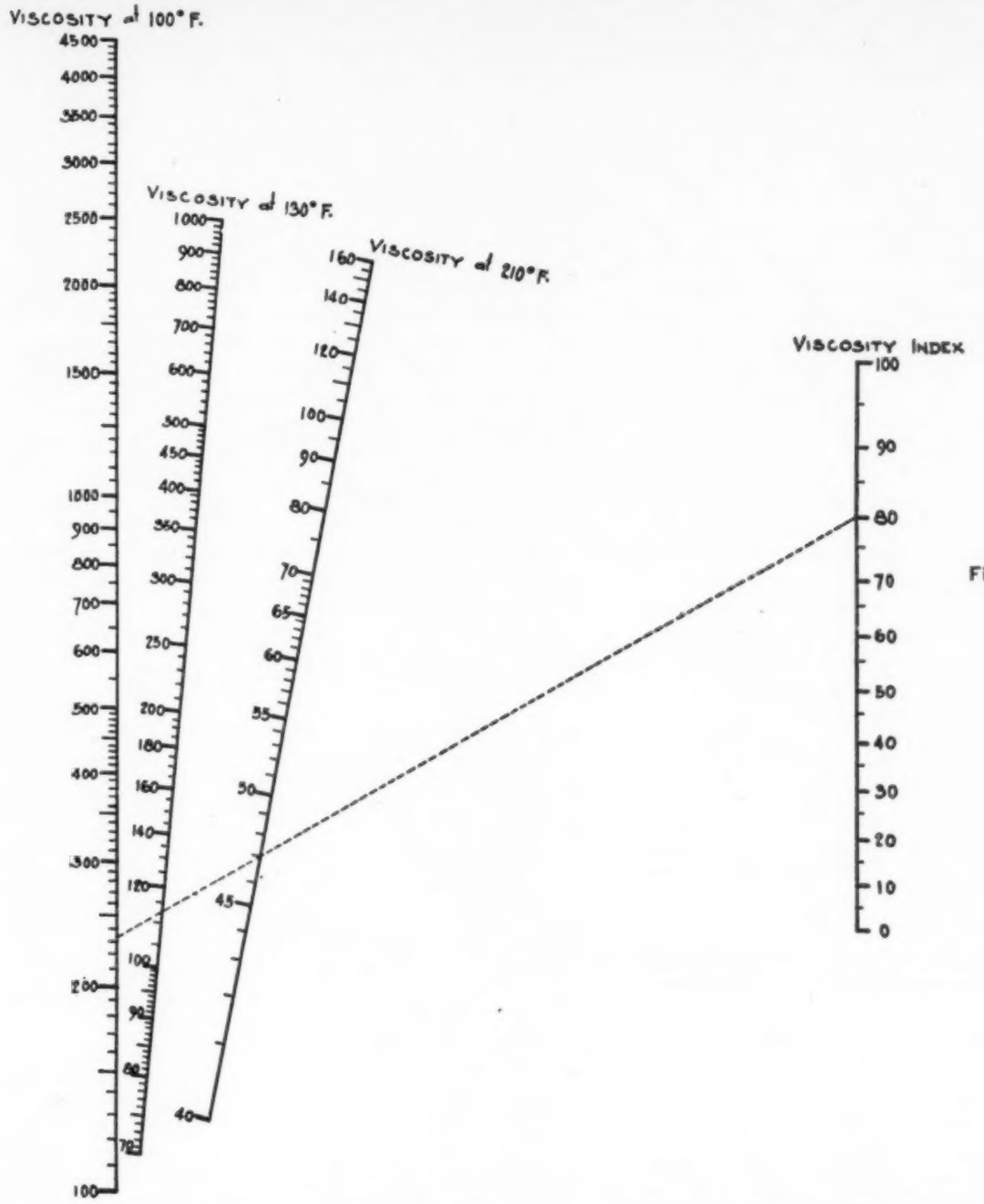


Figure 26 — Viscosity index alinement chart. (Courtesy Shell Oil Co.)

It is the preferred recommended practice to finish bushings in assemblies, where feasible, so as to minimize tolerance stack-up and obtain good bearing alinement.

The provision for fastening the bushing in place should be such that it will not bind or prohibit the outward expansion of the bushing. Set screws should not be allowed to bottom in the hole as this causes a restriction of the bearing during the period of expansion.

It is also common practices in the design of plain bearings, which have outside recessed surfaces, to make their aggregate thickness greater than those not so recessed. It has been found in practice that the greater

Figure 27 — Bronze bushing pressed into cast iron housing.

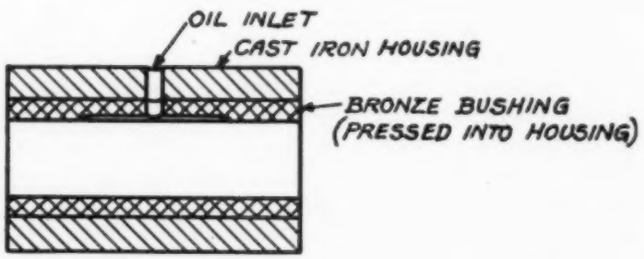
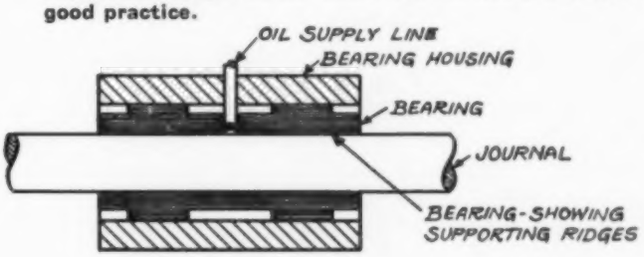


Figure 28 — This bearing is mounted with two outside supporting ridges at the ends. This is not considered good practice.



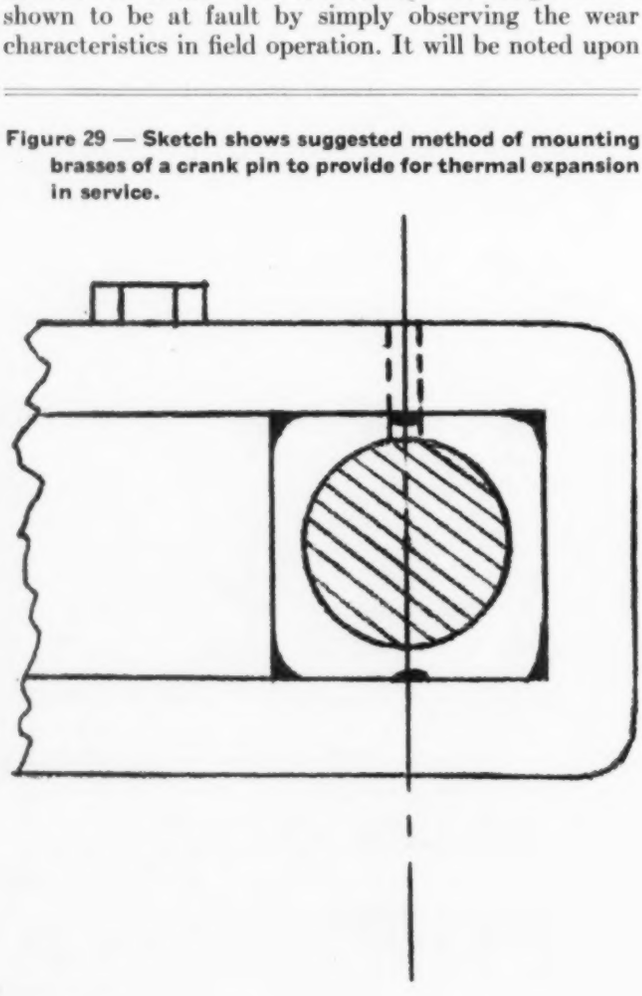
the thickness of bearing material between the journal and the housing, the greater must be the resulting inward expansion. Therefore, it can readily be seen that an excess thickness of bushing should be avoided.

As shown in Figure 28, the bearing is so designed as to offer only a skeleton support for the total imposed load placed upon the bearing proper. Quite often conditions are reversed so that the housing design offers the token support as illustrated.

The recessing of the outer surface of a bearing such as bronze has another undesirable effect in that the harder outer skin is removed on the tooled areas only, leaving the untooled areas with the surface skin under stress. This, consequently, has a tendency to warp or distort the bearing after tooling. Annealing may reduce materially, if not completely overcome, the tendency for the bearing to distort. Likewise the theory of incorporating the supporting ridges or rings to provide ventilation for the cooling of the bearing has been proven to be erroneous. Straight cylindrical bearings making contact with their housing throughout their entire outside surface would have a far greater heat conducting capacity than where supporting ridges or rings are employed.

Where a bearing is supported in the housing by ridges or rings, it is evident that the unsupported part of the bearing tends to expand outwardly, whereas the parts of the bearing corresponding to the surfaces supported on the outside, must expand inwardly and thus in turn present an uneven bearing surface to the journal. Although the fitting and machining of the bearing may be well within the limits of accuracy, the design can be shown to be at fault by simply observing the wear characteristics in field operation. It will be noted upon examination of the bearing surface that bright spots indicating metal to metal contact have developed in the proximity of the outer supporting ridges. Lessening of the desired load carrying capacity of this given bearing becomes quite evident when it is found that only a small portion of the bearing is in actuality supporting the imposed load.

Figure 29 — Sketch shows suggested method of mounting brasses of a crank pin to provide for thermal expansion in service.



A suggested method of mounting a crankpin bearing providing for thermal expansion in service is illustrated in Figure 29. The two edges of the half-bearings should be "brass bound," that is, they should bear solidly against each other and should exert a pressure against each other somewhat in excess of the maximum crankpin load. The outer surfaces of both half-bearings near these edges should be relieved so as not to bear upon the straps, as shown, somewhat exaggerated in Figure 29. The four corners of the bearings should be similarly relieved so that the horizontal thrust will be mainly borne upon the surfaces falling within the area of the horizontal projection of the crankpin. A bearing assembly thus constructed expands with the first slight increase of temperature, relieving the crankpin instead of clamping it as when these precautions are not taken.

17. Miscellaneous Bearing Applications

Railroad bearings are forced to operate under conditions quite different from general plain bearing applications and these conditions should be considered in determining the characteristics of the materials used. The bearing design most generally used is not a full bearing but rather a partial bearing. Lubrication in most cases is effected by the use of wool waste and oil, the oil being fed to the lower surface of the journal by the capillary action of the waste.

Railroad type bearings are designated by journal sizes 5 × 9, 5½ × 10, 6 × 11, etc., each size serving a bracket of load limits. In such sizes, the first figure represents the nominal journal diameter, in inches, while the latter represents the nominal journal length in inches. The 5½ × 10 size is the predominating size used in service.

As a journal is worn in service, the normal procedure is to re-machine for further service, providing that the resultant dimensions do not exceed certain condemning limits. Bearing diameters are not redetermined to follow closely the given journal dimensions. Table XII shows the load range and wear range or condemning limits for some of the most commonly used journal sizes.

As noted the 5½ × 10 journal may have a diameter ranging from 5½ inches to 5 inches; the bearing, on the other hand, is furnished to a fixed bore of 5$\frac{9}{16}$ inches. Thus, the diametral running clearance may be anything between $\frac{1}{16}$ and $\frac{9}{16}$ inches. Nomenclature for dimensions, "H," "C," and "F" are given in Figure 30.

The bearing must fit itself to this wide range of variation of journal sizes plus the ever present problem of contamination in service operation. For this reason, most railroad type bearings are lined with a lead-base babbitt, the lining being ¼ in. thick. The bearing back is found in most cases to be a high lead bronze, the prevailing standard bearing back for 5½ × 10 journal has a weight of 17.13 pounds, and a thickness of $\frac{7}{8}$ inch.

Switchgear bearings operate intermittently and over a

limited arc, so that heat dissipation and temperature rise are not important factors. Unit pressures are very high, 1000–10000 psi, and lubrication is negligible. Hardened shafts supported on bronze, cast iron, or special thermosetting plastics are used.

Fractional horsepower motors are employed for general use and may be mounted at any angle, the bearing design is usually of the wick oil type. Steel backed, tin-base, babbitt bearings predominate in the field. For special applications, such as operation in gasoline, graphite bearings are employed. Light duty applications have included porous metal bearings while still other applications employ bronze, bronze on steel, copper-lead on steel, cast iron, aluminum, etc.

Mill type motor bearing loads may run up to 150 to 200 psi as on gear drives, belt drives, etc. Oil ring lubrication is most commonly used, but general purpose motors are sometimes fitted with wick-fed bearings.

Tin or lead-base babbitt cast in a steel liner is general practice, whereas for unusually heavy duty service bronze and copper-lead bearings are employed.

Turbines, generators, gear drives and similar large installations require extreme care in manufacture to assure proper alinement. Where correct machine practice is employed, undue loading of the bearing material is minimized so that loadings up to 200 to 250 psi are found possible, while also providing an ample factor of safety.

Tin-base babbitt, lead-base babbitt and high lead-bronze have offered the best bearing service performance on units of these types, although the tin-base babbitt is usually preferred because of its superior corrosion resistance. For auxiliary turbine bearings, such as those used in valve gear and oil pumps, bronzes are used. Due to combination of high temperature,high intermittent loading and small arc of rotation experienced with valve gear bearings, bronzes are believed to be mandatory.

Instruments generally operate at slow speeds and intermittently, must turn frequently under low torque, yet be free of play and wobble. Although some are called upon for operation under extremes of temperature, most operate at or near room temperature. Many instrument bearing assemblies because of these stringent service requirements and relatively small size are of the pivot type and utilize hardened steel pivots resting in jeweled bearings. The bearing jewels may be of natural stone or pressed from glass. Scoring and wear are minimized by making the mating parts of dissimilar hard materials.

Electric timing motors contain bearings of copper, bone fibre or bronze, etc., usually employed with hardened and polished steel shafts. Low wear under boundary lubrication conditions is desired for these bearings operate under relatively high loads.

Electroplated bearings are sometimes employed in the automotive and diesel phase of the steel industry. From a metallurgical point of view, the grain structure of plated metal or alloy bearings is considerably finer than the equivalent cast structures generally employed. Precision plating of bearing alloys, under present available practices, can compete with the equivalent commercial thermal processes, and enjoys the added advantages of more accurate control of mechanical dimensions. The conventional type overlays are found to range from 0.001 to 0.005 in., depending upon the application, and include such compositions as pure lead, lead-indium, lead-tin-copper, tin-copper and silver.

Past research and experience covering bearing materials have demonstrated, within limits, the thinner the bearing metal the higher the fatigue life of the bearing. It has also been noted that where electroplating of the metals which reduce seizure is applied over the known fatigue resisting bearing materials, a definite benefit in bearing service life and reduction of wear on the mating parts have been realized.

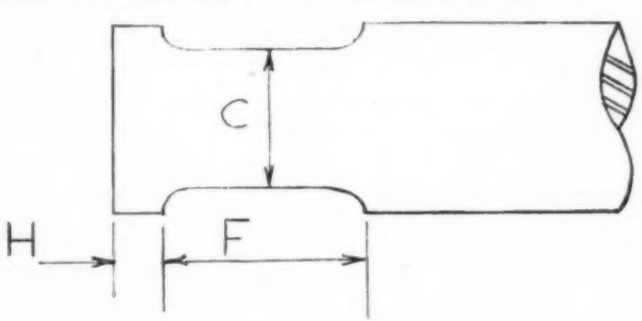
Steel back precision bearings have largely replaced the casting of tin-base babbitt directly in the case and rods of automotive and diesel engines. The most apparent disadvantage noted with the latter mentioned practice being the lack of bond and poor fatigue resistance.

Fatigue strength is the primary factor in the selection of the most advantageous bearing material. The adoption of the continuous strip casting technique and introduction of the thin-wall bearing has contributed heavily to the possibility of increased fatigue strength, due to providing better mechanical and physical properties in the finished bearing. This process employs a low carbon steel strip, ranging in thickness from 0.043 to 0.131 in., and in width from 4 to 6 in., fed into a casting machine at a predetermined speed. This technique is used in casting the lead and tin-base white metals, the copper leads, the leaded-bronze and combinations of leaded-bronze and tin-base in the form of the trimetal bearing. The strip is passed through a furnace where it is heated to approximately 2000 F under conditions conducive to good bonding between the strip and the bearing metal. Continuous casting is accomplished through alternate use of two induction melting furnaces worked on an alternate charging and pouring practice. After casting, the strip moves from the casting furnace to a cooling chamber. The strip then moves under a punch press and is cut to the desired length commensurate with convenient further processing in the coil form. After milling, rolling, and grinding,

TABLE XII

Nominal capacity of car, lb	Total weight on rail, lb	"H"		"C"		"F"	
		New	Condemned	New	Condemned	New	Condemned
80,000	136,000	3/4	3/16	5	4 1/2	9	9 11/16
100,000	169,000	3/4	3/16	5 1/2	5	10	10 11/16
140,000	210,000	7/8	3/16	6	5 1/2	11	11 11/16

Figure 30 — Sketch gives nomenclature for Table XII.



the strip is cut off to the proper length for the size bearing desired and formed into half round shells.

Extreme care is taken in shaving the parting line surfaces, and in broaching the inside diameter of each half shell to the specified tolerance limits. Inspection of the physical dimensions is based on measuring the length of circumference and the wall thickness rather than the inside and outside diameters.

Bronze back bearings are found in diesel engines as main and connecting rod bearings; motor support bearings; armature bearings; railroad main and side rod bearings, in addition to railroad journal bearings, electric motors, etc. It has been necessary to line bronze alloys with the white metals for various reasons, such as conformability, embeddability, seizure resistance and corrosion resistance.

Centrifugally cast lead-tin bronze bearings have been offered as a means of providing greater fatigue resistance. This type bearing with approximately 0.002 in. of lead-tin overlays has proven to be quite adaptable to the many applications where conventional static cast bronze bearings have not sufficed. Heavy duty loading in excess of 4000 psi on projected area with shafts of approximately 160 Brinell hardness have been reported as being satisfactorily met by employing this type bearing.

Grid type bearings which combine the good surface properties and embeddability of soft bearing alloys with the high strength and fatigue resistance of hard bearing alloys were developed to overcome the known variations and attendant problems resulting therefrom with most of the common bearing materials.

The practice of drilling holes in bearings with insertion of grease, graphite and other known lubricating mediums has been in vogue for quite some time, for applications where lubrication is marginal. In recent years this principle has been applied to heavy duty bearings by knurling the copper or silver surface which had previously been applied to the steel backing by either thermal bonding or electroplating. The knurled surface, having impressions in the form of inverted pyramids, is filled in with lead or babbitt, the excess bearing metal being machined off, leaving a surface of base material covered with pockets of bearing material. For best results this surface should contain at least 40 per cent by area of the bearing alloy and may contain 100 per cent lead. Satisfactory results are obtained with knurls of 20–50 pitch and 60–80 degree angle, depending on the particular service required. These give surfaces with approximately 20–50 indentations per linear inch with the indentations varying in depth from 0.008 to 0.024 in.

Grid bearings approach the fatigue strength of the base metal. Grid type bearings have been very successfully used in high load applications where dirt is a major offender to successful bearing life. Soft babbitt in the grid pockets tends to absorb and retain foreign matter such as dirt particles passing through the bearing zone, and thereby minimizes the tendencies of the bearing being circumferentially grooved by these entrained particles.

The thermal conductivity of grid bearings is essentially that of copper or silver, since the pyramidal structure of the matrix eliminates any interference from the lead alloy.

Porous metal bearings are made from metal powders, and of various compositions. The analysis of the bronze type is roughly ninety per cent copper, and ten per cent tin, with an oil content of twenty-five per cent by volume, and a porosity of equal value. The copper averages 250-mesh screen size, while the tin is somewhat finer. These powders are mixed thoroughly, then compressed in automatic presses to the required size and shape, to form briquettes. After briquetting, they are heat treated by sintering operations forming a true alloy. In bronze, the tin is found to be molten during the sintering cycle, while the copper remains solid, hence the resultant porosity. After sintering, the bearings are submerged in oil for impregnation, and finish sized in a punch press to the desired tolerances. Further impregnation is found necessary after the sizing operation to insure that a full charge of oil is taken up by the bearing.

Bearing clearances as low as 0.0002 in. on a $\frac{3}{8}$-in. shaft and 0.0005 in. on a $1\frac{3}{4}$-in. diameter shaft have been found possible in field applications. These clearances would be too small for general steel mill practice. Acceptable speeds vary from zero velocity to 60,000 rpm on small diameter journals. Where iron powder base is employed in the manufacture of the bearing, the permissible load rating has been reported at zero velocity, as ranging from 20,000 psi up to 80,000 and 100,000 psi. These latter mentioned bearings are intended primarily for low velocity and extreme-duty applications.

Composition bearings, or phenolic resin bearings as they are sometimes referred to in the steel industry, are employed for several specific applications, the most dominant being that of roll neck bearings. Successful operation with this type of bearing material has been noted where only water has been employed as the lubricant. Water, having a viscosity of only one, therefore has a tendency to greatly lower the coefficient of friction where used as the lubricant.

Figure 31 shows the friction characteristics of a composition bearing at pressures from 3000 to 4000 psi and speeds from 125 to 2100 fpm. This test was conducted with clean, fresh water at about 25 to 30 C (77 to 86 F).

Figure 32 shows the viscosity of water as the function of temperature, and indicates that the viscosity is cut in two by raising the temperature from 20 to 50 C (68 to 122 F). In practice where higher friction is encountered, it is believed that some breakdown of the water film takes place developing localized hot spots and

TABLE XIII

COMPOSITION BEARINGS — DUTY LOAD AND SPEED RATINGS

Load	Pressure
Light	Up to 500 psi
Medium	500 to 1500 psi
Heavy	1500 to 4000 psi
Extra heavy	Over 4000 psi

Load	Rubbing speed
Light	100 to 4000 fpm
Medium	150 to 3000 fpm
Heavy	250 to 2500 fpm
Extra heavy	Additional coolant and lubricity mandatory

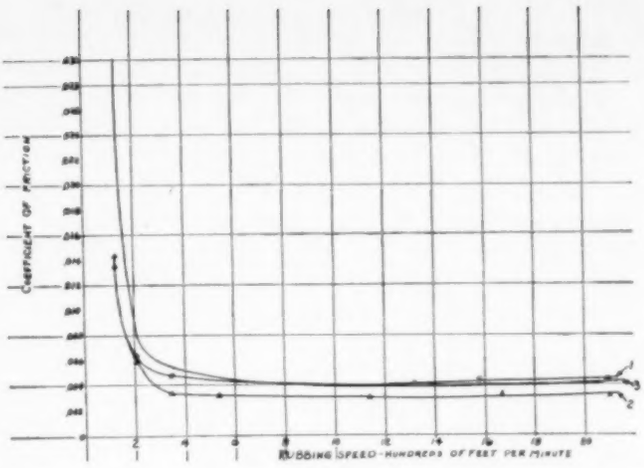


Figure 31 — Curves give variation of friction with rubbing speed.

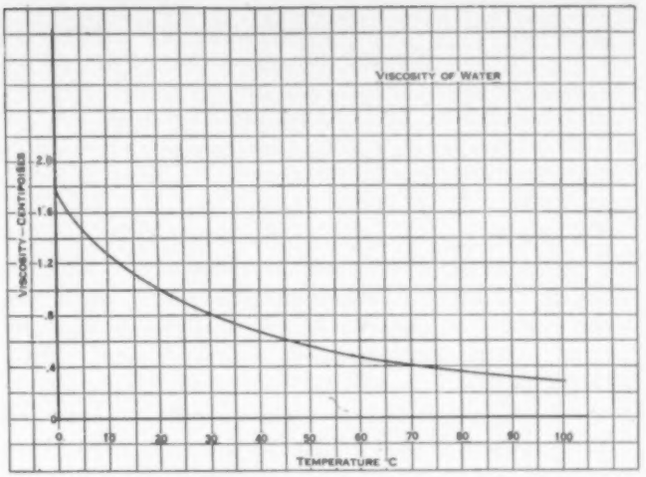


Figure 32 — Curve illustrates variation of viscosity of water with temperature.

resulting in increased rate of bearing wear.

From several tests run to date, it is concluded that successful operation of composition roll neck bearings, supplied with a copious stream of water, can be realized up to a maximum water temperature of approximately 45 C (113 F). Smoothness of the mating surface is mandatory for satisfactory field operation.

Composition bearings have a low heat conductivity (approximately 2 Btu per sq ft per in. thickness per hr per degree Fahrenheit), heat conductivity for bronze is about 400 to 500 times as great. They should not be used at temperatures in excess of 300 F.

A general rule for calculating the quantity of water required for composition bearings in gallons per hour (gphr) may be taken as equal to:

$$\text{Gphr} = \frac{(\text{D} \times \text{W} \times \text{f} \times \text{rpm})}{8000} \qquad (21)$$

where D = diameter of roll neck in inches
W = total load on bearing in pounds
f = coefficient of friction, which for normal calculations may be taken as 0.008

The heat generation at any instant is equal to:

$$\text{H}' = \frac{\text{f} \times \text{P} \times \text{s}}{778} \qquad (22)$$

where f = coefficient of friction
P = pressure in psi
s = rubbing speed in fpm
H′ = Btu per sq in. of bearing per min

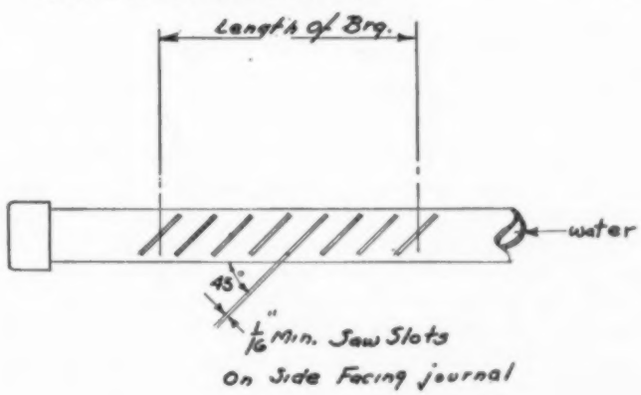
Loads and speeds for composition bearings are given in Table XIII.

In order to operate composition roll neck bearings at their highest efficiency, clean, cool water must be supplied for both cooling and lubrication. A typical method of applying the water is shown in Figure 33. This water must be applied correctly and in sufficient quantity, the volume being more important than pressure. Roll necks should be ground smooth, including fillets. Swabbing of the necks with either a mineral oil or soluble oil during the shut-down periods prevents the formation of rust on the necks and thereby minimizes the rate of bearing wear. Automatic spray applications of a soluble oil emulsion on the roll neck, at the time of mill shutdown and also before starting up, has been found to be of definite benefit to extended bearing service life.

As would be expected, water provides the lowest coefficient of friction when employed as the lubricant for composition bearings. However, on several slow speed applications, the usage of either oil or grease has been completely satisfactory. Caution must be exercised in determining the heat dissipation required, i.e., where oil is used as the lubricant, a flow sufficient to carry away the heat generated must be provided. In some instances the insertion of bronze thermal plugs in holes drilled in the composition bearing will assist materially in conducting the heat through the bearing, thereby making possible the installation of this bearing at speeds which would not be possible with the conventional composition bearing. Where the speeds and pressures are of low order, the product handled by the machine on which the bearings are mounted quite often provides sufficient lubrication, i.e., branning machines used to clean tin plate, thereby eliminating any additional lubricant applications. Graphite impregnation of the composition bearing during manufacture widens the range of applications demanding little or no additional lubrication on installations where speeds and pressures are moderate.

Carbon-graphite bearings are formed from carbon and

Figure 33 — Sketch shows a suggested design for water spray for composition bearings.



graphite powders which are compressed to shape under high unit pressures, then furnaced at temperatures exceeding 3000 F. During the processing, certain size changes take place. When broad limits can be permitted, further finishing can be omitted. However, if close tolerances are necessary this type bearing is ground to size or shaped with a tungsten carbide tool or diamond tipped tool.

On certain shapes and sizes, a tolerance of 1½ per cent on the inside and outside diameters can be realized, with an acceptable minimum tolerance of 0.010 in. whichever is the greater. On length, the tolerance can be held to 10 per cent of the dimension with a minimum of 0.040 in. and on projections, a limit of 4 per cent will be held with a minimum of 0.010 in.

The customary method of finishing carbon-graphite bearings is by grinding with wheels of about 36 grit for roughing, and 60 grit wheels for finishing. Grinding is done with an average wheel speed of 5000 fpm. Where a high degree of smoothness is desired, lapping and polishing is employed. Ordinary finishing operations are done dry, but water or oil may be desired in special cases.

Tapped holes, blind holes, intricate shapes, thin flanges, corrugations and keyways are not desirable. Wall thicknesses of less than 3/16 in. should not be specified. Metal backed bearings are used for applications encompassing high unit pressures or high temperatures. Being under compression, the carbon-graphite insert will expand and contract with temperature differentials at approximately the same rate as the metal backing.

This type bearing material has the ability to withstand the action of a number of chemicals. Dry grades should be used on equipment handling chemicals. Steam turbine camshaft bearings, thrust bearings, baking oven bearings and mill roll neck bearings are typical steel mill applications where lubrication is employed. Under 100 psi at 300 fpm and 250 F, carbon-graphite bearings can be operated dry or lubricated as desired. The fine porosity of the porous grades permit the use of very light fluids as a lubricant, and kerosene, water or solvents are used.

In determining the permissible loads that can be carried on carbon-graphite bearings, the following formula can be used:

$$\text{Rpm} = \frac{\text{L} \times 46{,}000}{\text{W}} \qquad (23)$$

where Rpm = maximum shaft speed
W = total shaft load (*not* psi)
L = bushing length in inches

This formula is based upon dry applications and on a conventional "PV" factor of approximately 12,000, where P is in psi bearing load, and V is in fpm shaft surface speed. A factor of 7–10 can be used to cover the increased values where lubricant is used.

The porosity of the carbon-graphite bearings is expressed as that portion of the total volume of its mass taken up by the pores. As the apparent density (manufacturing range of carbon-graphite bearings is from 1.65 to 1.86) reaches the real density (manufacturing range of carbon-graphite bearings is from 2.00 to 2.26) the porosity is reduced. The per cent porosity may be figured numerically by means of the following equation:

$$\text{Per cent porosity} = \frac{\text{Real density} - \text{Apparent density}}{\text{Real density}} \times 100 \qquad (24)$$

The coefficient of friction for the various grades of carbon-graphite bearings generally used ranges from 0.04 to 0.25. Where lubricant is used, the coefficient of friction is lowered accordingly. The coefficient of linear thermal expansion for a temperature range of 75 to 625 F is only 0.0000015 in. per in. per degree Fahrenheit. The thermal conductivity ranges somewhere between that of copper and cast iron. Carbon-graphite is also accepted as being an electrical conductor and nonmagnetic.

Cast iron bearings have been used for moderately low speeds. They have been found to be reliable only at low speeds. Although they can be used at high speeds under certain ideal operating conditions, they are not considered reliable, and may seize suddenly and disastrously. High grade gray cast iron, such as meehanite, like tool steel contains no free ferrite and when properly machined, fitted and run-in will perform quite satisfactorily when used as a bearing material. The matrix consists entirely of pearlite except where special wear properties in combination with improved toughness are required, in which case the casting is made with a base matrix of sorbite or sorbite in combination with pearlite.

Kingsbury thrust bearings are used for thrust loads in vertical and horizontal bearings. A rotating collar (called runner in vertical bearings) and stationary pivoted segments or "shoes" are the vital elements of the bearing. As they run in a bath of oil, which is not under pressure, the oil clings tenaciously to the collar surface, and is drawn between the collar and the shoes, forming separating films of high load-carrying capacity. This is made possible by the pivoting action of the shoes which are free to tilt microscopically, thus permitting the formation of wedge-shaped films, with the thick end on the entering side. A running journal assumes a relative position which tends to form a tapered oil film. Figure 34 illustrates how the pivoting action of the shoes in the thrust bearing develops the tapered oil film which actively supports the imposed load. The oil films are continuously renewed, merely due to the rotation of the oil-flooded collar; the working surfaces being separated by the oil film as long as the shaft turns. Consequently, the loads carried are generally found to exceed conventional type bearing ratings, where due to the magnitude of the imposed load, the oil film is ruptured, and the pivoted segment feature of the bearing making this difference possible. Standard bearings have from two to eight shoes according to type. (Figure 34 shows three and six shoe assemblies.)

The loads carried per square inch of shoe area depend on shoe size, oil viscosity and speed. The higher the speed, the greater the load capacity. Tilting of the segments may be found in the order of no more than one or two thousandths of an inch; yet this tilting is essential for proper functioning of the bearing.

The film is under maximum pressure near the center of the loaded area, and the sum of the unit pressures is equal to the load carried. The coefficient of friction of Kingsbury thrust bearings is approximately from 0.001 to 0.005, depending on the unit load, speed and viscosity of the oil. Since the loads are so concentrated and speeds

are often high, the oil becomes heated by its own "shearing" friction. To remove the heat, the oil is cooled either by radiation or by an auxiliary oil cooler, which may be located within the housing or on the outside. It is circulated either by automatic devices provided in the design within the housing or by an outside pump.

As already indicated, either horizontal or vertical shaft mountings may be employed. The arrangements for oil circulation are necessarily different in the two cases. Most standard applications for horizontal mountings include a device called a pumping ring which, operating on the viscosity principle, delivers a volume of oil sufficient to flood the bearing quickly at the start and maintains a rapid circulation. Where design does not permit this action to take place, an auxiliary oil pump is utilized. In vertical mountings, the bearing assembly is permanently submerged in an oil bath to a point above the bearing surfaces. Oil circulation within the bath is automatic, and no pump is required except when external cooling is used. An oil retainer is employed between the shaft and bearing to prevent the escape of oil downward on the shaft of vertical mountings.

Flood lubricated oil film bearings are essentially totally enclosed precision type plain bearings. They comprise the second class of bearings in the introduction. Due to their high load carrying capacity they are employed as roll neck bearings on various types of hot and cold rolling mills in the steel industry.

Bearings have been built for rolls of nominal body diameter as small as 8½ and as large as 56 in. The continuous full load radial capacity of the bearings for the 8½-in. roll is 92,000 pounds each, and for the 56-in. roll is 5,250,000 pounds each. An unbroken oil film maintained between the rotating and stationary members of the bearing assembly is mandatory in general, although brief and occasional periods of operation under conditions of incomplete hydrodynamic lubrication can be tolerated without damage.

One particular type of bearing of this class embodies a construction in which the assembly with the chock is removable as a complete bearing unit. Figure 35 is a cross sectional assembly of a bearing and chock used on the larger diameter rolls. The assembly consists primarily of a hardened and ground alloy steel roll neck sleeve keyed to the tapered roll neck, and a steel bushing whose inner surface is coated with a relatively thin lining of bearing metal. The mating tapers of the roll neck and the roll neck sleeve are non-locking which makes for easy removal of the bearing assembly from the neck. Rotation of the bushing in the chock is prevented by a dowel screwed into the side wall of the chock in proximity to the oil supply pocket on one side of the bushing and intersecting the side wall of the bushing. Positioning of the bushing in this manner serves to line up the oil supply channels in the chock bore and bushing, permitting a constant supply of lubricant under pressure to the bearing load zone via the oil supply pockets on each side of the bearing. The oil is allowed to flow freely from both ends of the bushing and drains to oil sumps, which are interconnected with the oil outlet, in turn connected by flexible hose to the drain piping, and so to the receiving tank in the oil cellar.

Incorporated in the bearing assembly for the thrust side of the mill is a high capacity double acting roller thrust bearing, loose fitted and keyed to a reduced diameter neck extension. The outer races of the thrust bearing are enclosed in a roller bearing housing which reinforces the races against bursting stress. Radial clearance is provided around the roller bearing housing to prevent radial loading of the thrust bearing. The outer races of the roller bearing and its housing are positioned axially by a shoulder in the bore of the end plate bolted to the chock, and by the roller bearing end plate bolted to the chock end plate.

The bearing assembly is held in position on the

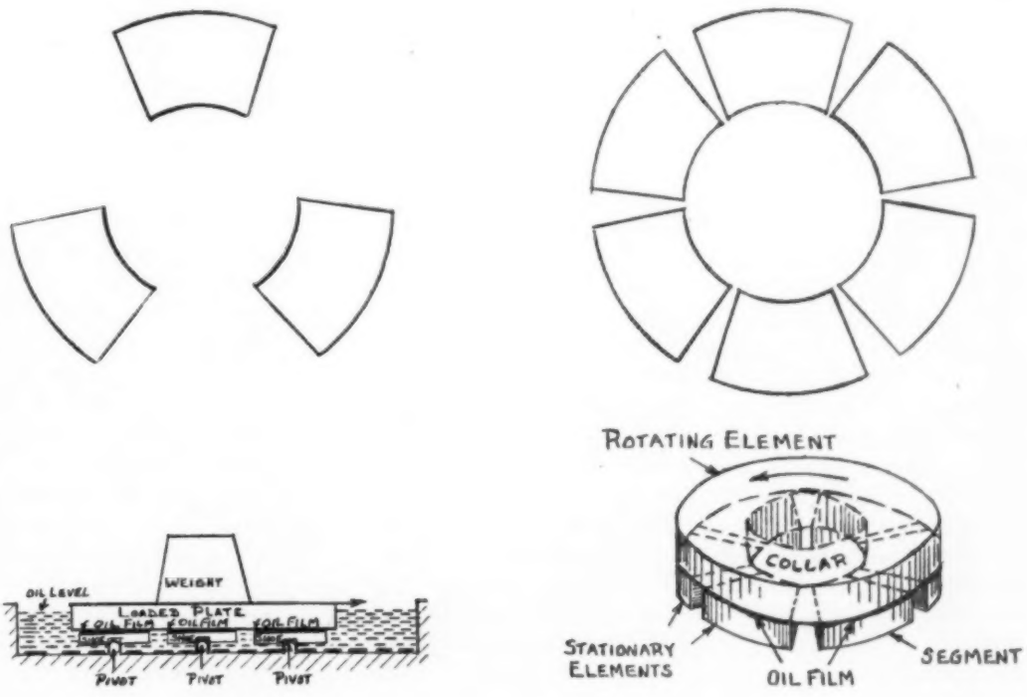


Figure 34 — In the Kingsbury thrust bearing, two to eight shoe assemblies may be used. Unit on left is a three-shoe assembly and that on right is a six-shoe assembly. The sketch on the bottom left shows how the oil film or wedge forms under the pivoted shoes and supports the loaded moving plate.

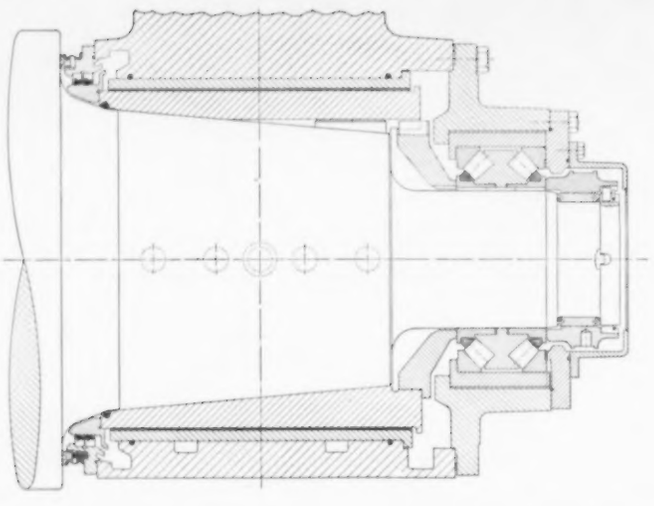


Figure 35 — Cross-section of precision flood lubricated oil film bearing mounted on roll neck.

tapered roll neck by a locknut threaded over a split threaded ring seated in a groove in the roll neck. The nut is locked in correct position and prevented from backing off by the application of a vernier key at the outboard end, and this key which is loose fitted is held in position by a spring retainer. By tightening the locknut, the inner race of the roller thrust bearing bears against the sleeve ring and the sleeve ring bears against the end of the roll neck sleeve, seating it on the tapered neck. In this way the rotating parts, including the inner race of the roller thrust bearing, are integral with the neck of the roll. As the outer races of the roller bearing are integral axially with the chock and as the chock is positioned in the mill housing window by keeper plates or latches, the roll is definitely positioned axially in relation to the thrust side mill housing. The roller thrust bearing is lubricated by separate oil feed which enters through the roller bearing end plate from a flexible hose from the main oil supply. The oil passes through the roller bearing and drains to the outboard sump in the chock meeting the oil from the radial bearing at that point.

On the non-thrust side of the mill, no thrust bearing is incorporated, and the roll neck sleeve is held in position on the tapered neck by a locknut which bears against the end of the sleeve. The roll is free to expand or contract in the non-thrust side bearing. Chocks are positioned in the non-thrust side housing by keeper plates, latches, or spacer bars from the thrust side chocks to the non-thrust.

The outboard end of each bearing and the end of the roll neck are enclosed by end covers for non-driven rolls. When rolls are driven, the end cap is omitted on the drive side and seals are applied in chock end plate or roller bearing end plate and operate on the outer surface of the locknut.

The oil flowing from the inboard end of each bearing is diverted to the oil sump by a flinger incorporated in a detachable sleeve extension bolted to the inboard end of the roll neck sleeve. To prevent escape of oil along the surface of the roll neck at the inboard end of the bearing, a gasket is used between the roll neck sleeve and the roll neck. Rubbing seals are incorporated in a detachable chock inboard end plate and operate on the outer surface of the sleeve extension to prevent entrance of water or coolant. For additional protection against water and/or scale, a ring of self lubricating bronze is provided as an end face seal. The ring is piloted on an extension of the inboard end plate and is held against the end of the roll barrel by light spring pressure. A water proof flexible synthetic rubber boot connects the ring to a flange on the inboard end plate to prevent by-passing the water seal ring.

The smaller diameter roll neck bearings are supplied with double acting ball thrust bearings. In addition, many bearings are in operation using plain thrust bearings whose shoes operate on a flange at the outboard end of the roll neck sleeve.

Where an unbroken film of oil is maintained, the coefficient of friction for this type of bearing has been found to range from 0.0012 to 0.003. The selection of the oil viscosity for an oil film bearing is derived from the theory that an oil film can be formed in any bearing and can be maintained without interruption, provided that the factor viscosity $\times$ speed/load (usually written ZN/P) exceeds a certain critical value. The magnitude of this critical value depends in part upon the proportions of the bearing, but more particularly upon the relative hardness and surface finish of the mating surfaces of the journal and bushing. Obviously, parts having rough surfaces require more favorable conditions to form and maintain an unbroken oil film than are necessary with parts finished to a high degree of smoothness. Consequently, the permissible minimum value of the factor ZN/P must be determined experimentally, and can be employed with confidence only for bearings having substantially identical proportions and the same kind of surfaces.

In this type of oil film bearing, the journal is ground and the bushing bored to have a surface roughness of 2–4 and 35–45 micro-inches RMS respectively.

In actual practice it is essential that the oil viscosity be selected to produce ZN/P equal to or greater than the prescribed minimum value under the most severe conditions of high load and low operating speed. The minimum values determined are based to a large extent upon past experience. In installations having a moderate range of operating speeds, the selection of viscosity is not particularly critical; in such cases the viscosity may be chosen to produce a value of ZN/P well above the minimum. If the range of operating speed is large, as in the modern high-speed cold strip mill, selection of an unnecessarily high viscosity will lead to higher oil temperatures when operating at high speeds; in such cases the lowest permissible viscosity is selected.

Quantity of oil required to lubricate a bearing of this type is based on complete replacement of the oil film in a specified number of revolutions. Oil volume factors have been developed for each size bearing which when multiplied by the maximum rpm of the roll to which the bearing is applied gives the maximum gal per min of oil required. Basis on which the oil factors are figured is partly theoretical and partly empirical, and results in an over supply of oil or what is termed "Flood Lubrication." This type of lubrication not only gives the bearing an adequate oil supply, but tends to assist in dissipating the heat generated within the load zone of the bearing. Usage of orifice type nipples in the oil

supply lines with orifices drilled to calculated size makes possible a metered oil supply to each bearing. Through the orifices, the maximum oil requirement is supplied at maximum roll speed. As roll speed decreases, the volume of oil decreases automatically as each bearing functions as an oil pump.

Another widely used full journal roll bearing in the industry is similar to the one just described with one principal difference. Instead of a tapered roll neck with its mating steel sleeve, the bearing assembly employs a straight neck and a journal bearing to fit. Its principal of operation is basically similar to all well-designed full journal bearings, wherein only a small portion carries the load, the included angle varying between 90 and 120 degrees for different installations.

The loads and speeds under which this type bearing is used are comparable to the one previously described. Also like the tapered-neck roll bearing, a situation exists that calls for high viscosity oil at low speeds with high bearing pressure and low viscosity oil for high speeds and high bearing pressure. Mill practice in most instances depending on delivery speeds makes use of oils of viscosities from 1200 SSU to 2450 SSU at 100 F. Oil flows of between 6 to 8 gpm at pressures varying from 10 to 15 psi are quite ample to lubricate bearings with necks as much as 33 in. diameter.

As can be expected, considerable heat is generated in the bearing under these high load and speed conditions and as a consequence there are incorporated in the bearing several features intended to keep it running within a satisfactory temperature range. It must be remembered, incidentally, that these bearings are designed so as to be used on either end of the roll. Though this is so, they are not, however, interchangeable from top to bottom roll or vice versa.

A steel forging is machined and bored out to such dimensions that after centrifiugally babbitting and finish machining, a maximum babbitt thickness of 3/16 in. lines the bore of the bearing. For anchorage, some shells employ dove-tailed grooves beneath the babbitt; others have small square islands; some have circumferential grooves alone, and there are some under test with no anchorage at all depending entirely on a chemical bond between the babbitt and base metal. One cannot emphasize too strongly the importance in these precision bearings of proper bonding. Babbitt in the bearings must be high grade and consists usually of a 90 Sn 8 Sb 2 Cu percentage composition.

For best operation, clearances between the journal and bearing are held between 0.025–0.035 in. or approximately 0.001 in. per in. of diameter. Oil is fed under pressure into the bearing from its outside end past a leaf-spring loaded ball check. In some mills, orifices are incorporated in the place of the check to control flow into the bearing. Oil enters the bearing shell directly at its lowest point, and then splits off to both the right and left as it follows a path described by a labyrinth, under the pressure zone, (bottom bearing). The construction permits the oil to trace a continuous back and forth parallel path terminating at a point on each side of the bearing 60 degrees radially from the center line. At these two points, the last one of these holes running from one end of the bearing to the other is dead-ended, causing the oil to discharge into the bearing through small holes drilled at right angles to them. Accordingly, oil enters the bearing at both the trailing and leading edge of the pressure zone after it has previously absorbed some heat in passing through the labyrinth.

Once the oil enters the bearing some of it is drawn under the roll neck and some of it is simultaneously carried (pumped) up into the area directly adjacent to and above the bottom zone. These areas (one on each side) have been machined to a different radius, thus forming pockets for greater oil flow. It is possible thereby for more oil to flow through the bearing without necessarily increasing the flow through the load zone, a factor intended to help in keeping this type bearing cool. As the oil continues upwards another 75 degrees around the periphery of the roll neck, it reaches another series of small holes, free-bored and drilled at right angles to the face of the bearing through which it leaves the surface and eventually discharges past ball checks. It then flows through a passage around the outside periphery of the bearing formed by a square slot in the bearing chuck until it discharges through a pipe connection at the bottom. To prevent leakage of this oil between the circumferential joint formed by the bearing and the chuck, a "V" groove is machined on the outside surface of the bearing into which a "V" belt is inserted which upon assembly serves as a sealing device.

Oil circulation through the top bearing is identical except for the fact that since the labyrinth is also under the pressure area and whereas this area is now on top instead of the bottom, and since the oil still enters at the bottom, the oil necessarily flows through the bearing before it enters the labyrinth.

In common with all types of roll neck bearings and especially these precision bearings, it is essential to keep water and scale out of the oil and of course important to keep oil flowing in the bearings at all times.

With regards to means provided to insure proper and uninterrupted flow into and through the bearing, several practices have been developed. The spring-loaded check through which the oil enters the bearing must be very carefully maintained or else it is possible for oil flows to become erratic. Pipeline orifices are sometimes used in place of the ball check to overcome this hazard.

Another expedient used in many mills intended to keep the bearing area supplied with oil consists in scraping the surface of the babbitt with definite floral patterns, providing in this way tiny oil passages over the entire area.

Extra precaution is observed in machining the bearing surface to make sure that there are no sharp edges at the chamfers, and that free-bores of as much as 6 in. in length are made adjacent to the trailing and leading edge of the bearing to facilitate the formation of a hydrodynamic wedge. At times it is even found desirable to undercut the unloaded zone directly opposite the pressure area to allow for increased oil flow around this portion of the bearing.

To prevent the entry of water and scale, the bearing embodies several features. Two bronze split ring seals, held tight with garter springs, are assembled and fitted on each end of the bearing, one is fitted adjacent to the babbitt and the other is positioned a few inches away, its distance being determined by a spacer which along with the seals are held together by a retainer ring,

allen screws and gaskets appropriately located.

Proper fitting of seals is an essential requisite to trouble-free operation. If fit is too sloppy, oil loss is high accompanied by high water contamination. If clearances are too close, they stick and lift off the surface of the neck causing contamination and oil loss. Depending on the neck diameters and operating temperatures, standard end and side clearances are established to overcome this difficulty. Other expedients such as water and scale deflectors, baffles, different seal constructions, etc., are at times used to advantage.

The assembly with two seals in place on each end is a complete unit which is carefully slipped over the roll neck. Once installed, the bearing is limited in its lateral movement by the installation on the neck of a collar, collar nut and an adjustable lock ring — each of which is keyed to the journal as well as bolted to each other. The roll, with bearings on each end, is lowered into two chucks and the bearings are centered by means of dowel pins in the shell mating with holes in the center of the chuck. Simultaneously also, dowels in the chuck itself serve to open ball checks through which oil leaving the bearing has to flow. Mill end thrust is taken care of by a separately assembled roller bearing thrust retaining cage assembled on one end of the roll.

18. Bearing Design Influence on Machine Vibration — Self Excited Vibration

The vibration characteristics of a machine are influenced to a certain extent by the bearing design as well as the lubrication damping phenomena, the form or application of the bearing employed governs this consideration.

Poor alinement of plain bearings not only impairs their normal load carrying functions and reliability, but also with the otherwise normal amount of unbalanced vibration of the machine, may cause a hot spot on the journal which in turn aggravates the vibration tendencies of the journal assembly, such as a rotor of a generator, causing a still greater vibration so that it is often found necessary to shut down the machine. In this case the forces created are of sufficient magnitude to excite any resonant or near resonant members of the machine and the resultant increased magnitude of the original forces of unbalanced vibration may exceed satisfactory operating conditions.

A self-excited vibration known as oil-whip occurs not infrequently in machines employing oil-film type bearings. Usually the rotor is the major vibrating element, although the instability may be manifest to the same or greater degree in the non-rotating parts. The forces in this case which do work in support of oil-whip come from oil-film pressures. The vibration is characterized by relative motion of journal and bearing in an area which is usually circular or elliptical, and in the direction of machine rotation. The motion is often magnified in adjoining machine parts due to resonance. The frequency of oil-whip is generally less than one-half the running frequency. The clearance between the journal and bearing very often influences the relative stability under critical operating conditions; an increase in clearance evidently leads to stability for a position in the unstable region near the upper section of the transition line, whereas for an operating point in the same region near the lower right section of a transition line, a decrease in clearance would lead to stability. The provision of a circumferential oil groove in the bearing has also been found, under certain operating conditions, to be a powerful means of eliminating oil-whip.

In some cases stability is difficult if not virtually impossible to achieve using conventional oil-film bearings, hence it becomes necessary to employ a pivoted shoe or pad journal bearing which is inherently a stable type. This type bearing is not only incapable of exciting or maintaining a vibration, but also offers heavy damping to forced vibration caused by unbalance. This damping is also found to be effective in overcoming other unstabilizing influences arising outside the bearing.

19. Sub-harmonic Resonance Compared with Oil Whip

Another type of self-excited vibration which often occurs in rotating machines can arise from bearing conditions. This vibration known as sub-harmonic resonance is characterized by its fundamental frequency which occurs at exactly one-half, one-third, or any other submultiple of running speed; usually, however, the frequency ratio is one-half or one-third. It is thus a true subharmonic.

Sub-harmonic resonance can be maintained by periodic contact of the journal and bearing which can occur through combination of poor bearing alinement or excessive bearing loading, and unbalance vibration. Although the source of energy for the vibration does not originate in the bearing, this vibration has been excited, even with moderate unbalance conditions, and the only cure is improvement in the bearing design. Failure of all or part of the bearing surface sometimes results in this type of vibration.

Sub-harmonic resonance is very often diagnosed as oil-whip, and consequently oil-whip has been thought to have properties which in reality it does not possess. Positive identification of self excited vibration in rotating machines is quite easy with a graphic record of the actual motion, and extremely difficult without one. In the case of sub-harmonic resonance and oil-whip, positive identification is essential because opposite steps are required for correction. Increased speeds and loads demanded of older rotating machines will in turn require greater attention to the influence of bearings, and lubrication on the vibration of machines. Such vibrations may occur at speeds from 3600 rpm down.

20. Sealing Devices

In many machine designs, little or no thought is given to the incorporation of sealing devices in plain bearing applications as a means of controlling loss of lubricant or the infiltration of foreign contaminants within the load zone. This lack of thought, particularly on grease lubricated bearings, has had for many years the accompanying effects of unsightly conditions resulting from the excess quantity of grease being emitted from the bearing and dropping down over the machine to the floor. Considerable benefits can be derived by including a suitable sealing device in the bearing design to permit better retention of the lubricant, and to also exclude the foreign contaminants which are conducive to bearing wear.

Figure 36—Plain type seal, whose effectiveness depends on close clearances between the bore and shaft.

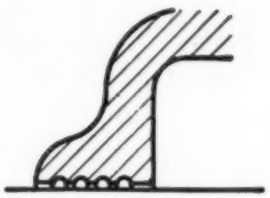


Figure 37 — This seal uses $\frac{1}{16}$-$\frac{3}{32}$ in. deep annular grooves packed with sealing grease.

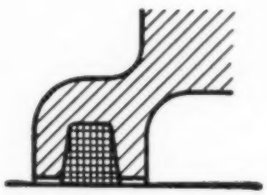


Figure 38 — A felt seal is assembled in a machined or cored felt-groove. The taper gives the necessary squeeze. There may be one or more grooves.

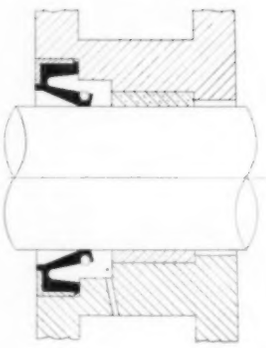


Figure 39 — This seal has a somewhat longer lip than some designs, which helps follow the shaft in case of wear. The seal is manufactured from a synthetic rubber flange vulcanized to the metal casing.

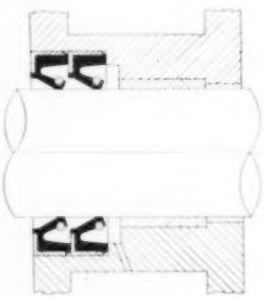


Figure 40 — The double tandem seal is used for difficult conditions. For the higher speeds, lubricant should be introduced between the two sealing units.

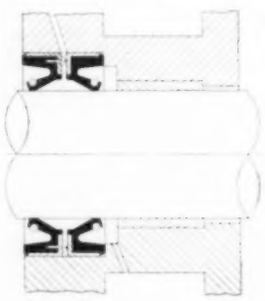


Figure 41 — In the double opposed sealing unit, the outer seal keeps out the dirt and the inner seal retains the lubricant. For medium or high speed use, lubricant should be introduced between the two seals.

Figure 42 — Another type of duplex sealing unit.

Figure 43 — Another type of double opposed sealing unit.

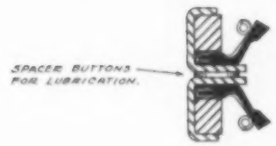


Figure 44 — A double opposed seal design with both sealing elements mounted in a single case.

Figure 45 — A duplex seal design with both elements mounted in a single case.

Figure 46 — This split seal is used widely with slow speed service, particularly in the steel industry when a solid seal cannot be used. Molded from synthetic rubber, the seal is designed to be fitted in a recess and held in place with a cover plate.

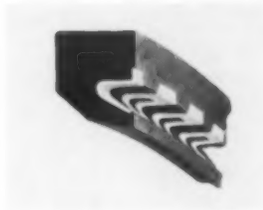
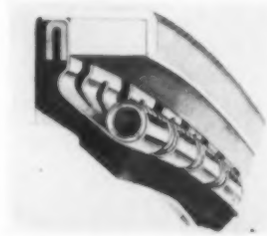
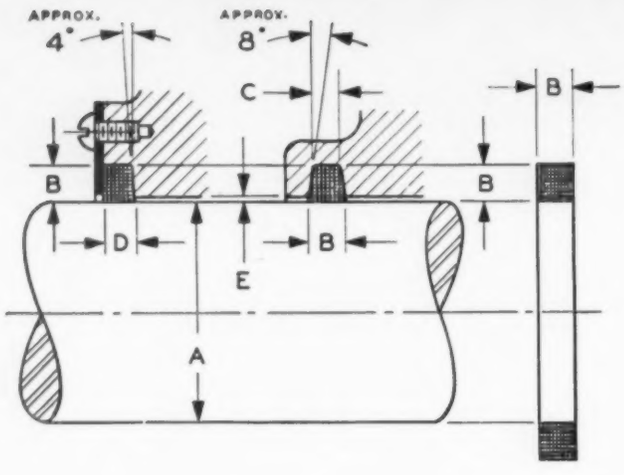


Figure 47 — Seal illustrated is commonly used on hot mill back-up rolls, as a water and scale seal. This is a large seal for heavy equipment, constructed in strip form to be wrapped around and clamped to any diameter supporting housing.

Figure 48 — This seal is made for roll necks over 8 in. and combines the properties of both a finger and a garter spring. The sealing member is molded of synthetic rubber and its flexibility permits high shaft deflections.





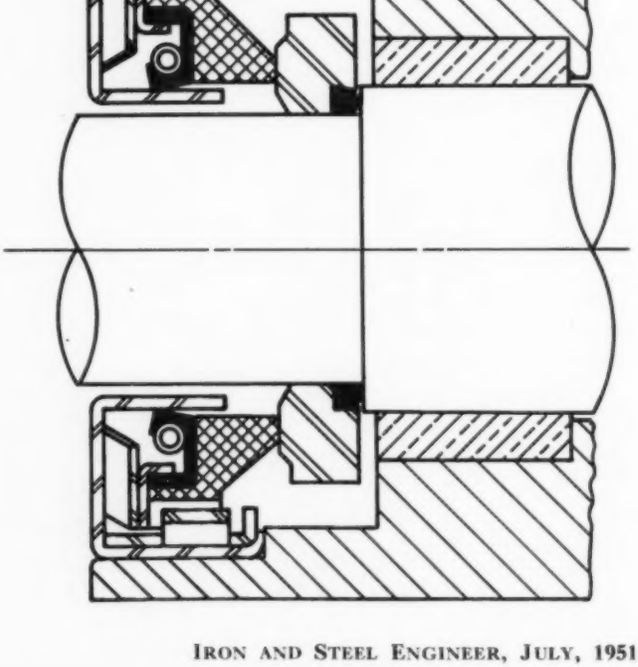
SHAFT A	B	C	D	E MAX.	Felt Specifications S.A.E. F-10 F-11 F-12 F-13 F-15	S.A.E. F-5 F-6 F-7	S.A.E. F-1 F-2 F-3
					Approximate Limiting r. p. m.		
1/2	1/4	3/16	13/64	1/64	6000	8000	12000
1	1/4	3/16	13/64	1/64	4000	6000	7000
1 1/2	3/8	9/32	5/16	1/64	3000	4000	5000
2	3/8	9/32	5/16	1/32	2000	3000	4000
2 1/2	3/8	9/32	5/16	1/32	1600	2400	....
3	1/2	3/8	13/32	1/32	1300	2000	....
3 1/2	1/2	3/8	13/32	3/64	1100	1700	....
4	1/2	3/8	13/32	3/64	1000	1500	....
4 1/2	3/4	9/16	5/8	3/64	900	1300	....
5	3/4	9/16	5/8	1/16	800	1200	....
5 1/2	3/4	9/16	5/8	1/16	700	1100	....
6	3/4	9/16	5/8	1/16	700	1000	....

Figure 49 — This sketch and table gives recommended grooving dimensions for various seals. Data is particularly applicable to the designs shown in Figures 36 through Figure 38. Proportions may be changed when necessary to suit available space. In the sketch the housing to the left has a straight bore, and the felt ring is held by a steel retaining plate. In the sketch to the right, the housing has a machined or core type groove with tapered sides to furnish the necessary squeeze to the felt ring. One or more grooves may be used. (15)

Seals for rotating shafts include several distinct forms and the range of their respective usefulness should be thoroughly understood. Several types of sealing material and designs are available for the many and varied field applications. These include: leather, composition and rubber type in either, single or multiple, interior or exterior design. Also employed to a lesser degree are the annular groove, grease groove, felt and cork type sealing members. Such seals will retain the lubricant and exclude dirt for most operating conditions. However, with critical operating conditions such as high pressure lubricant, very dirty or wet applications, or where shaft wear must be held to an absolute minimum, more intricate seal construction is sometimes demanded. The latter include as typical applications, the packaged type end face seal, axial face type seal or labyrinth seal. As its name implies, the labyrinth seal is effective by virtue of the intricate clearance path established between the rotary and stationary members. Surface finish and dimensional accuracy are most important for successful operation of the various types of sealing devices employed.

Leather, composition and *rubber* are utilized for sealing members most generally in the form of "flange type" seals. This type of construction employs a flanged shape sealing member with a wiping lip which is pressed very lightly against the shaft by means of garter springs, finger springs or the seal construction itself. The spring is generally employed in order to provide a predetermined pressure against the wiping lip, thus effecting a more positive sealing member. Although the normal practice is to mount the wiping lip towards the bearing, there are field conditions encountered where a reversal of the lip mounting away from the bearing is deemed advisable. During periods of heavy dust and water conditions encountered in field operation, the latter mounting practice has been found to be most effective, especially where grease is used as the lubricant. In other cases it may be found necessary to employ two or more sealing members with the lip mounted in such a manner as to provide the greatest amount of protection from entry of outside extraneous matter, or control over the loss of lubricant from the bearing proper. See Figures 39-48. Where leather seals are employed, oak leather may be used for shaft speeds up to 700 lineal fpm with exceptionally clean operating conditions and adequate lubrication present. For higher speeds ranging up to 1000 fpm, chrome retanned leather is recommended. Still higher speeds and temperatures demand special attention in the selection of the material, synthetic rubber and silicone rubber offering the greatest promise to date.

Figure 50 — Sketch shows a typical end face seal which is used when this type of seal is necessary or where the lubricant is under appreciable pressure.



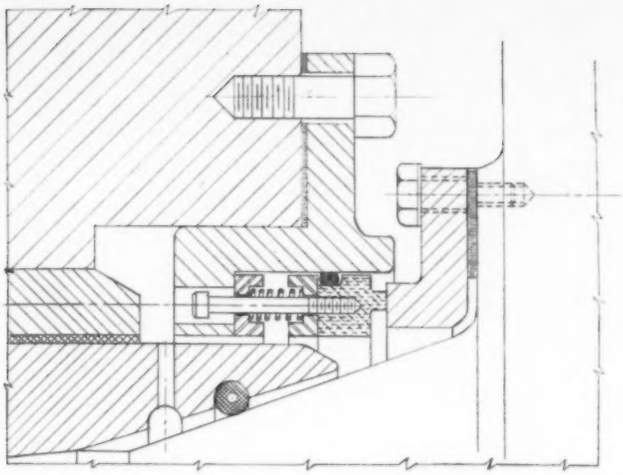


Figure 51 — The sealing faces on the axial face type seal are kept in contact by spring action.

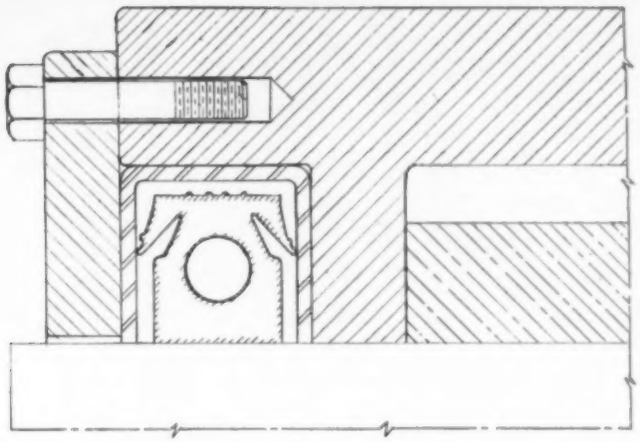


Figure 52 — The face type seal shown is used primarily on larger shaft diameters.

(Note: Feet per minute = shaft diameter in inches × rpm × 0.26.)

End face seals are often employed in the steel industry, one type commonly resorted to is the packaged type shown in Figure 50. This seal construction has a stationary main section of the closure, sealing against a floating seat. This permits greater flexibility and assists in maintaining the seal surfaces in good alinement. The seal ring is usually a carbon base compound, although hard steel, bronze and other materials may be used where necessary. The seat is usually a metallic material suited to the specific needs of the application.

One axial face type seal employs highly lapped sealing faces which are at right angles to the shaft and kept in contact by spring action. Wear of the shaft and surface finish of the shaft are found to be less critical with sealing devices of this type as compared to closure or lip type seals. However, the initial cost is generally considerably higher which tends to direct their usage to higher speed, higher pressure or more critical applications. See Figure 51.

This type seal generally utilizes a replacement seat against which it operates, and thus the seal face and the seat against which it wears may be economically and conveniently replaced without incurring the major expense of rebuilding or renewal of the shaft.

Satisfactory field performance on speeds up to 6000 fpm and pressures up to 1000 psi have been reported where seals of this type have been incorporated.

A prime requisite of seal design is that of providing sufficient flexibility to meet such contingencies as manufacturing tolerances, bearing wear, axial movement of the shaft, etc. To insure the maximum life of the axial face type seals, the manufacturers have established safe operating ranges including a total axial tolerance of plus or minus 0.035 in. with suitable provision for not less than 0.090 in. total wear. Flexibility is also important since radial tolerances may range from 0.002 to 0.005 in. To compensate for initial or axial movement due to wear, a spring or series of springs are employed to keep the seal faces in contact. The materials selected for construction must be such that they will not "work harden" or crystallize excessively. Especially compounded synthetic rubbers have proven to be the most satisfactory to date for the flexing members. The mechanical appliance to which the seal is to be applied, and the medium to be sealed, are the factors that materially influence maximum speeds permissible.

Another face type seal has a seal element which is produced from an extruded length of synthetic rubber material which is vulcanized into one continuous section to fit the shaft for which it is required. The outside diameter of the surface of the element is then split for a short length to allow the assembly of a garter spring to be provided in the internal cavity, so as to permit gripping of the element on the journal with the desired tension. The split section is then cemented shut with the result that the garter spring is completely enclosed inside of the element. (The seal element fits in housing shell which is exaggerated in Figure 52 to show construction of sealing lip.)

The housing shell is generally made of medium hard brass extruded and butt-weld jointed to a perfect end to end match. The inside surfaces are held in parallel planes within 0.005 in. on circumference, and free from all surface imperfections. No tool marks or scratches are permitted. Accuracy and smoothness of the outside are also demanded to insure good mechanical fit in the housing.

As will be noted this specific design offers the same features as the conventional mechanical type end face seal in regard to eliminating the attendant wear of the shaft or roll neck. Cross-sectional area of this seal design also permits interchangeability with the so-called closure or lip type construction which reduces the initial cost of installation. However, manufacturing difficulties limit the usage of this design to larger shaft diameters only.

Labyrinth seals, while considerably more expensive, are often found to be superior to the other types, especially where operating under very adverse conditions. To be effective they must be accurately machined and fitted in addition to being properly designed to suit the individual operating conditions encountered. Quite often as an adjunct to the labyrinth type seal a slinger is provided to supplement the seal proper. Filling of the clearance space of the labyrinth type seal with a grease of good sealing properties as well as water repellency and resistance to high temperatures serves as a very effective additional control medium. See Figure 53.

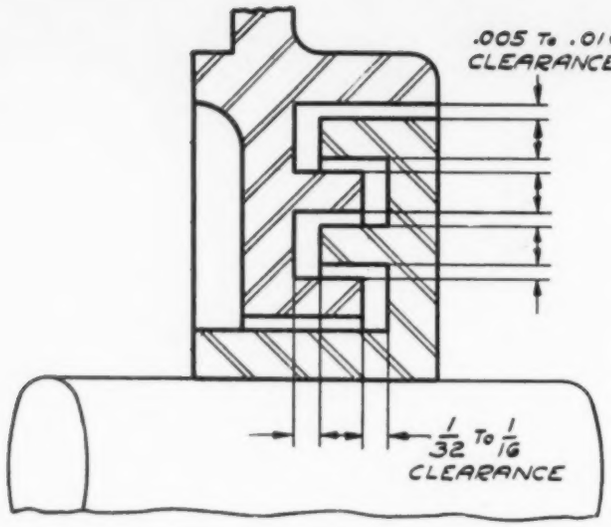


Figure 53 — The basic design of the tongue and groove labyrinth seal is given in this sketch. Recommended clearances are also shown. The labyrinth seal may operate efficiently under conditions where other seals may fail. This type is used for precision bearings.

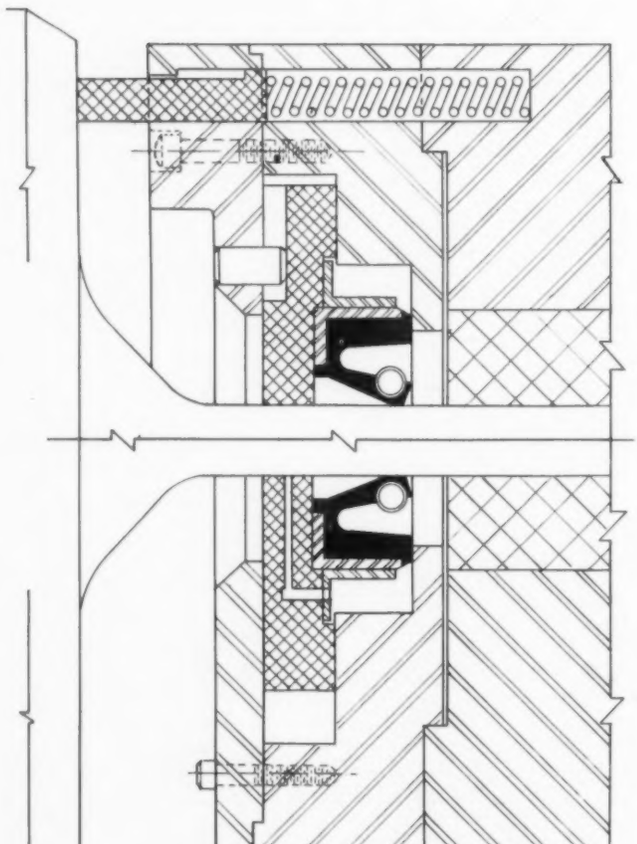
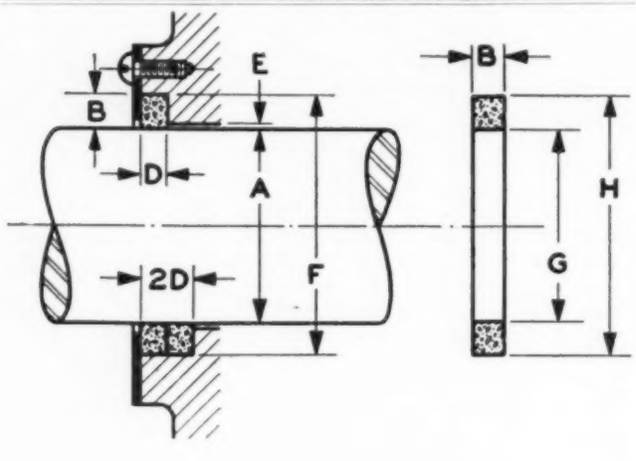


Figure 54 — This seal is recommended for use with water lubricated, nonmetallic bearings where extreme wear is expected. The seal is mounted in a nonmetallic carrier which floats on the shaft or roll neck; and as the nonmetallic bearing wears, this floating element stays with the shaft and carries the seal.

Felt seals (see Figures 38 and 49) are most useful on shafts having peripheral speeds under 2000 fpm with lubrication present and good surface finish and hardness of shaft. Felt has sufficient resiliency to permit some shaft deflection or runout and frequently will operate satisfactorily against poorer surface finishes if other conditions are favorable. Pressed felts of 100 per cent wool have proven to be superior to woven felts or those containing vegetable fibre fillers. When cutting felt seals of the split washer type, a bias cut is recommended. Negative clearance should be allowed on the inside diameter of all types, commensurate with the shaft speed range involved. For shaft speeds under 900 fpm an interference fit of 2 to 3 per cent should be



CORK RING DIMENSIONS

Shaft A	B	D	E Max.	Cork Ring G	Cork Ring H
½	¼	3/16	1/64	A − 1/32	F + 1/64
1	¼	3/16	1/64	A − 1/32	F + 1/64
1½	3/8	5/16	1/64	A − 1/32	F + 1/64
2	3/8	5/16	1/32	A − 1/32	F + 1/64
2½	3/8	5/16	1/32	A − 1/64	F + 1/64
3	½	7/16	1/32	A − 1/64	F + 1/64
3½	½	7/16	3/64	A − 1/64	F + 1/64
4	½	7/16	3/64	A	F
4½	¾	11/16	3/64	A	F
5	¾	11/16	1/16	A	F
5½	¾	11/16	1/16	A	F
6	¾	11/16	1/16	A	F

Figure 55 — Recommended dimensions for cork rings are given in this illustration.

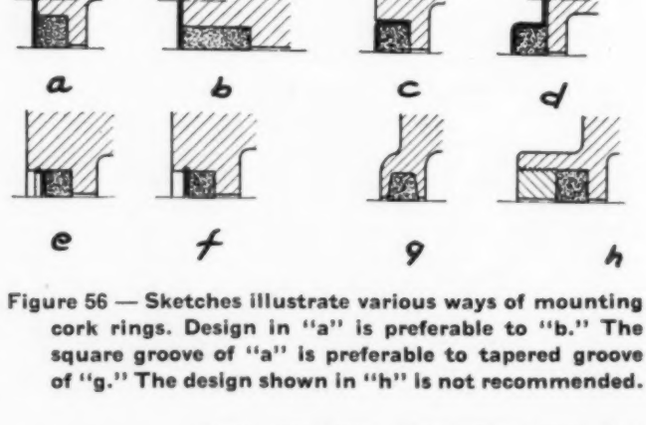


Figure 56 — Sketches illustrate various ways of mounting cork rings. Design in "a" is preferable to "b." The square groove of "a" is preferable to tapered groove of "g." The design shown in "h" is not recommended.

determined. Speed ranges above 900 but less than 2000 fpm require a one-half per cent to one per cent interference fit. For speed ranges above 2000 fpm the inside diameter of the felt seal should be the same as the shaft diameter to eliminate excess overheating.

Cork, used as a sealing element, is composed of clean natural cork, finely ground and held together by a suitable binder. See Figures 55 and 56. It is recommended that the grooves provided in the metal retainer be straight-sided and not tapered as commonly employed for felt assemblies. It may be desirable to incorporate two or more rings in the design. In general the cork seal ring should have an approximately square cross-section which is preferable to one having a long contact surface with a relatively thin wall. The designs which embody a threaded mounting or seating member are not recommended for cork seals, due to the twisting strain exerted therefrom upon the cork ring as mounted. The cork seal rings should be compressed slightly from the sides to eliminate any tendency to turn with the shaft, the amount of squeeze may vary from $\frac{1}{32}$ to $\frac{1}{16}$ in. depending on the size of the ring and the density of the material. Cork seals should not be employed where the sealing ring must be assembled into an internal groove as shown in Figure 56h. Another limitation in the usage of cork seals is that they should not be used where constant operating temperatures are in excess of 150 F. Before using cork seals they should be soaked in oil for approximately five hours minimum. At assembly, apply a small amount of grease to the inner surface of the rings.

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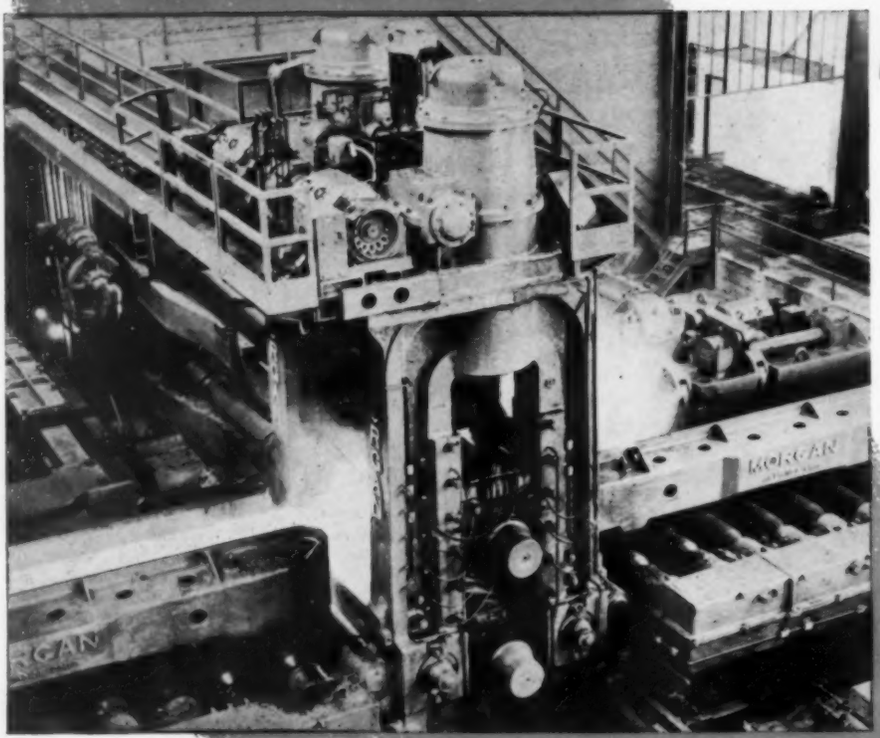

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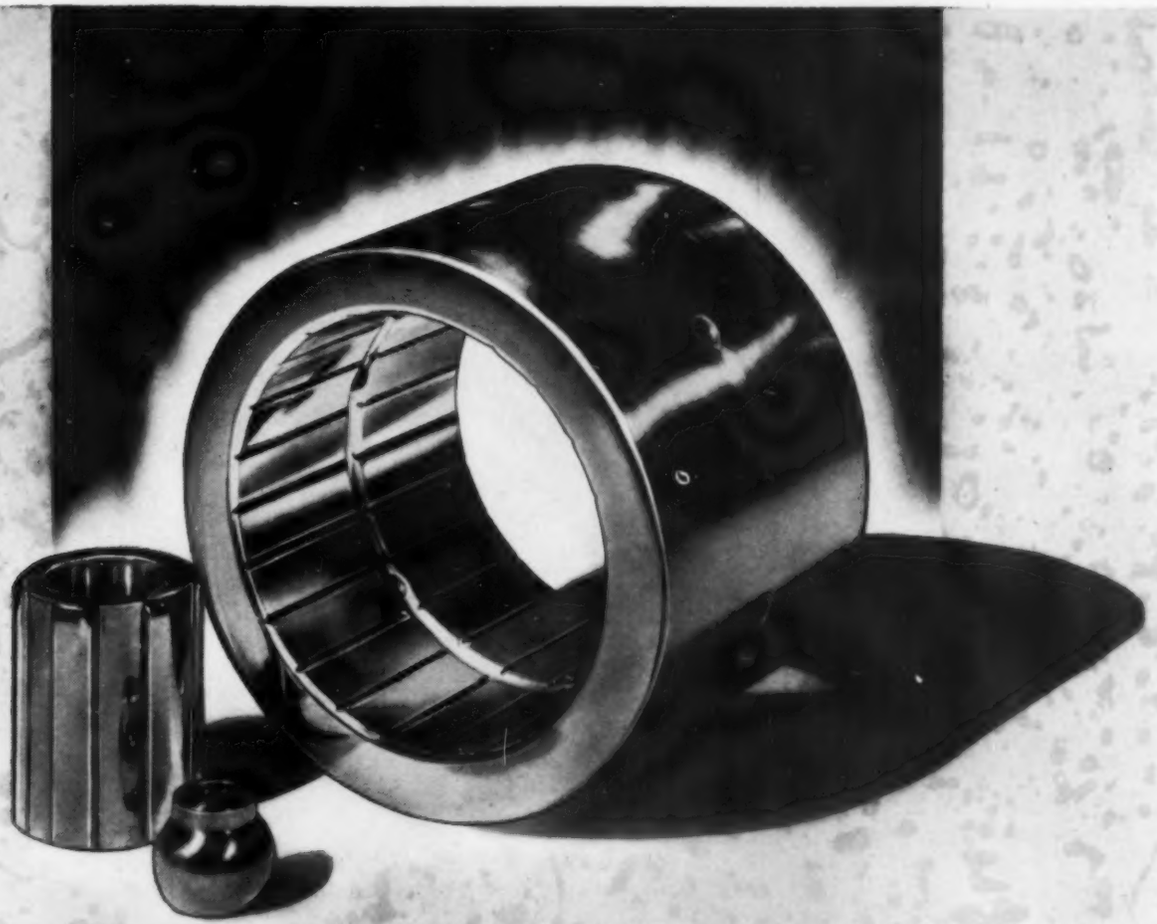

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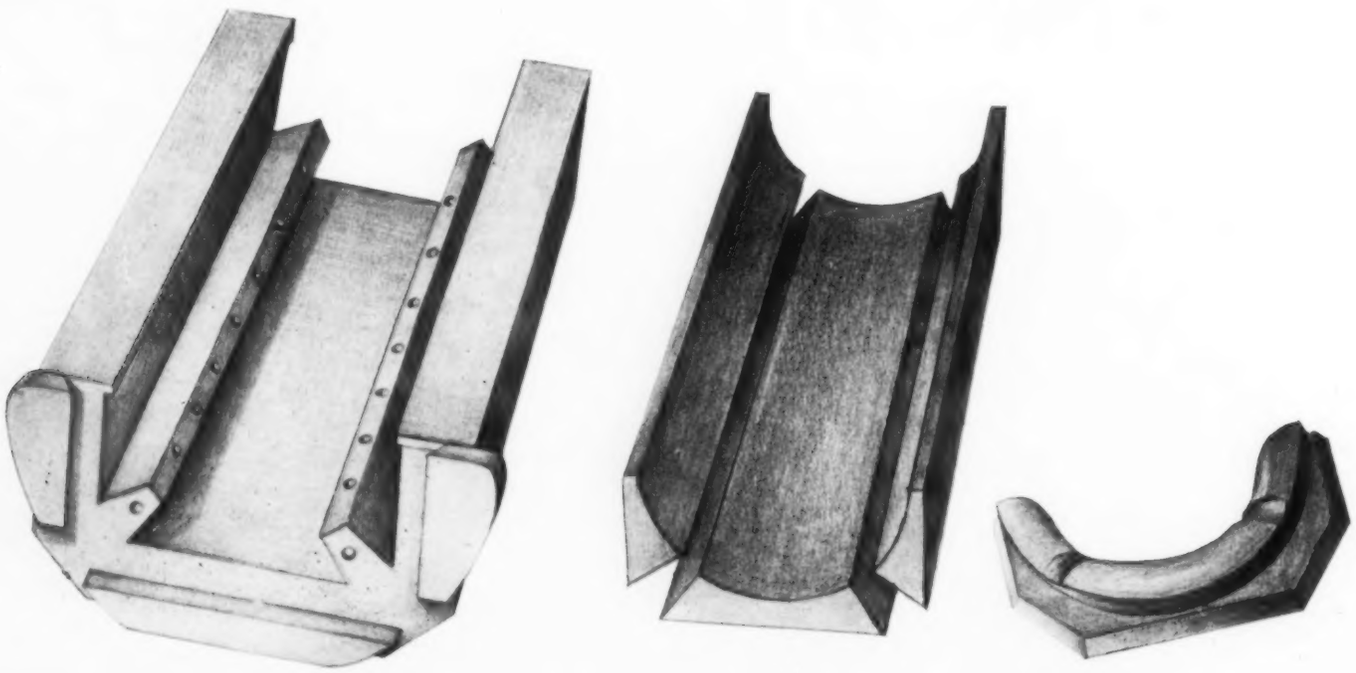

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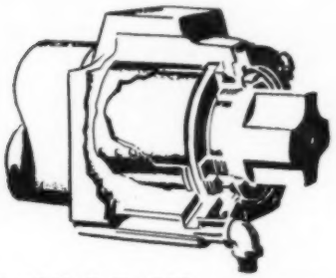

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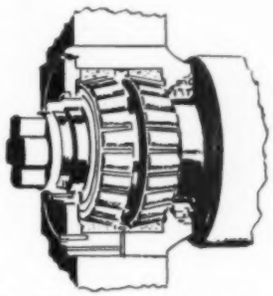

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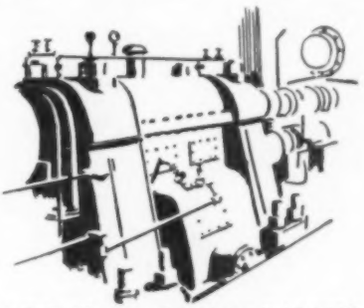

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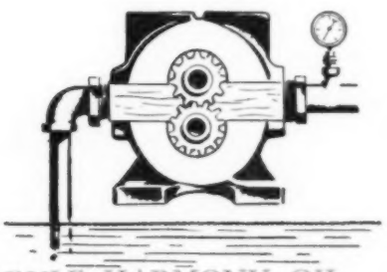

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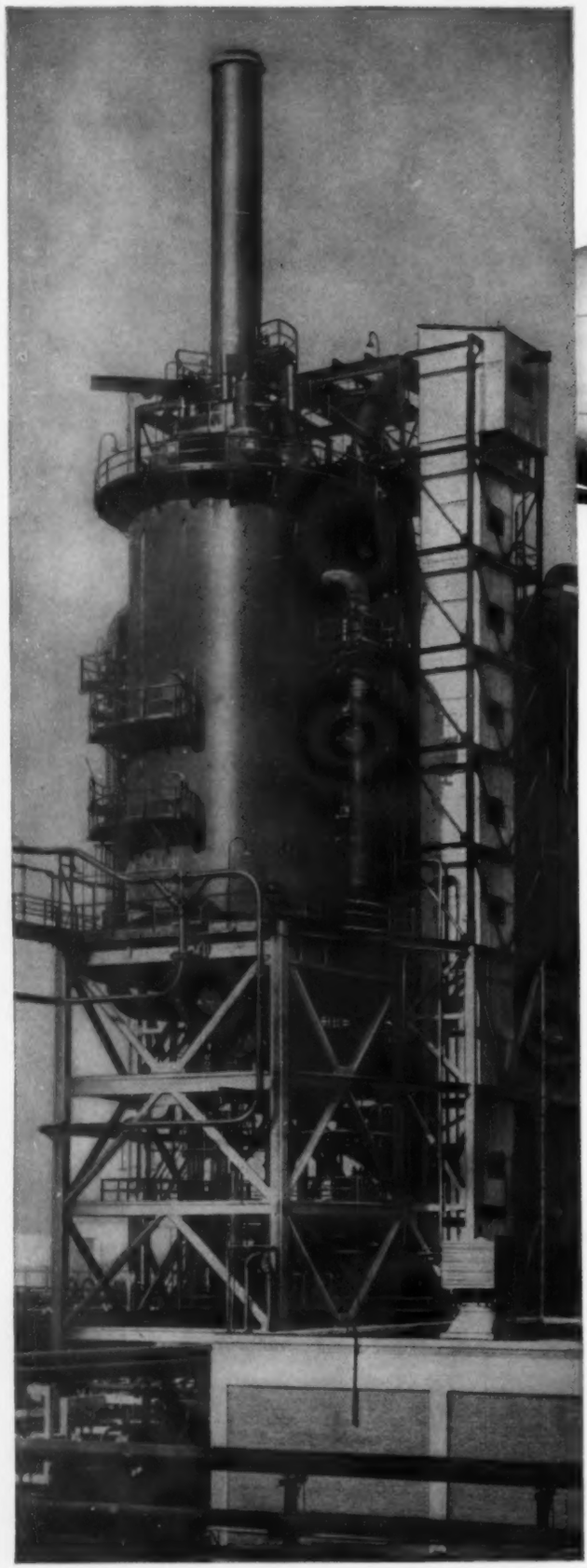

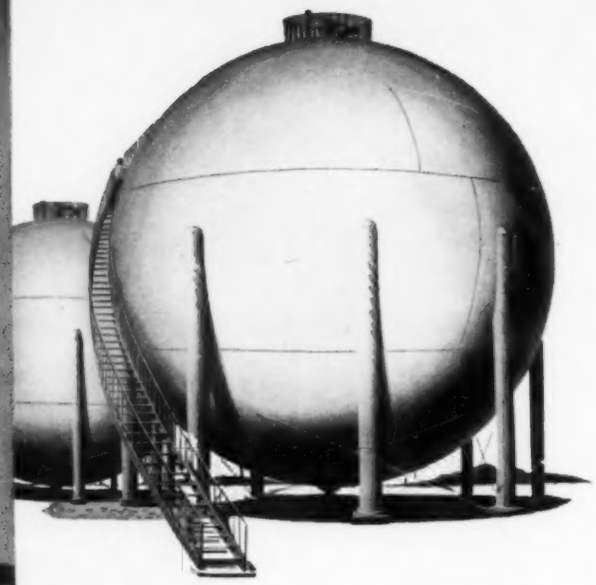

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TOTAL MORGOILS PURCHASED FOR STEEL MILLS		44
Eight Companies Rolling Copper and Brass First Ordered		420
Subsequent Orders by these Companies		524
TOTAL MORGOILS PURCHASED FOR COPPER AND BRASS MILLS		32
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Subsequent Orders by these Same Companies		618
TOTAL MORGOILS PURCHASED FOR ALUMINUM MILLS		4,343
Number of MORGOILS in Use on 2-High Mills	19	3,032
Number of MORGOILS in Use on 4-High Mills	31	
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Number of 4-High Reversing Hot Mills Using MORGOILS		
Number of 4-High Reversing Cold Mills Using MORGOILS		
Number of MORGOILS Used on 2-High and 4-High Aluminum Foil Mills		388

3,783 MORGOILS Have Been Purchased for use in the United States

3,592 MORGOILS Have Been Purchased for use in Foreign Countries

We would like to receive your inquiries for the installation of MORGOIL Bearings in new or existing mills of all types.

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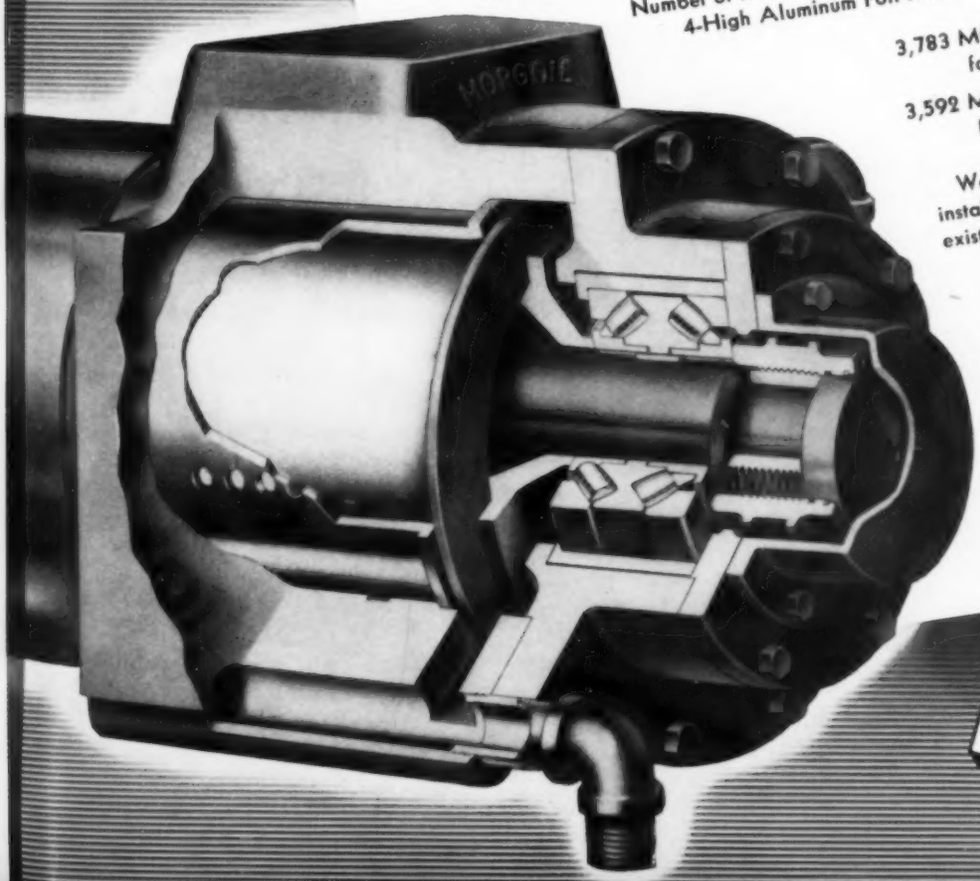

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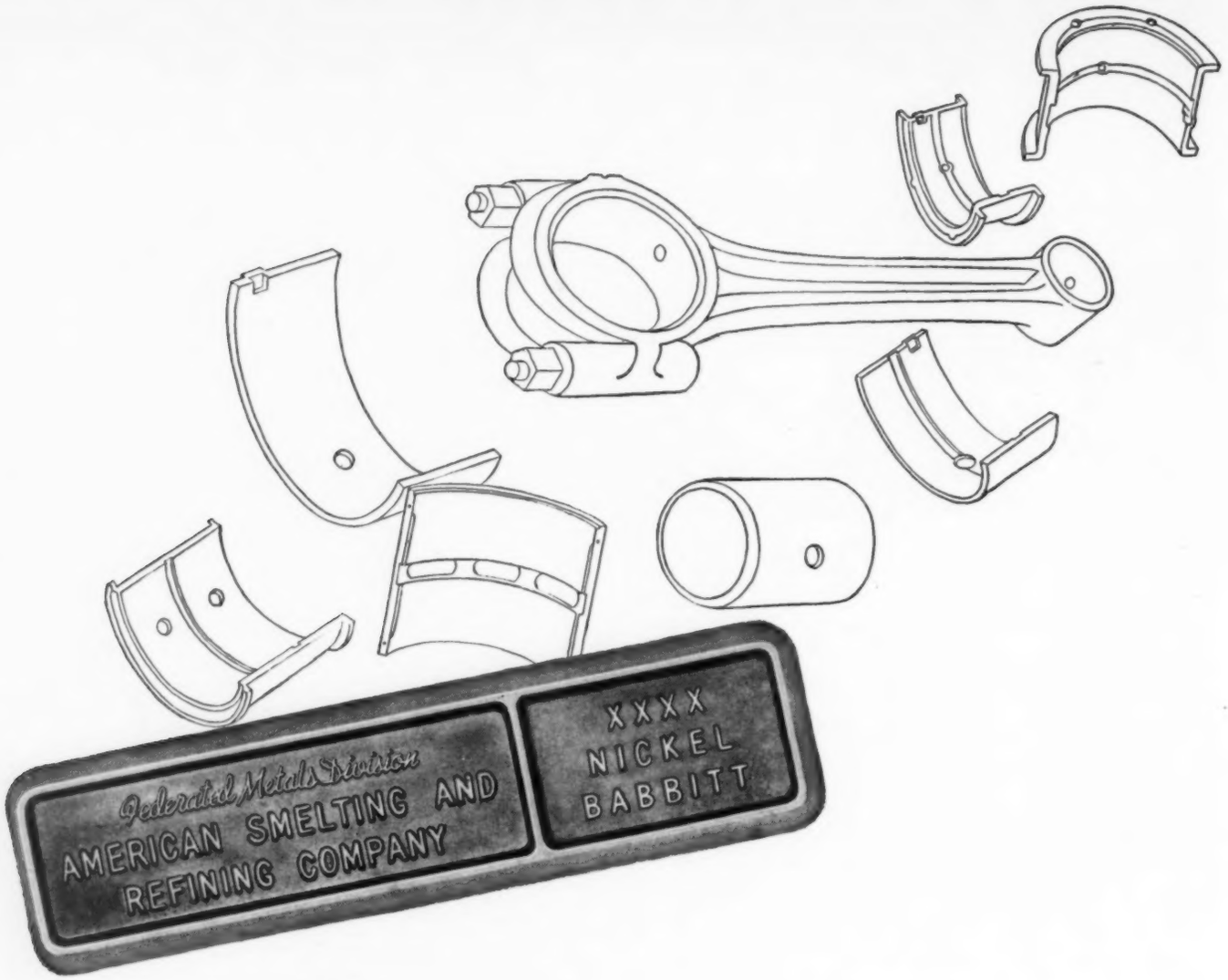

to be sure

RE-LINE BEARINGS WITH FEDERATED BABBITT!

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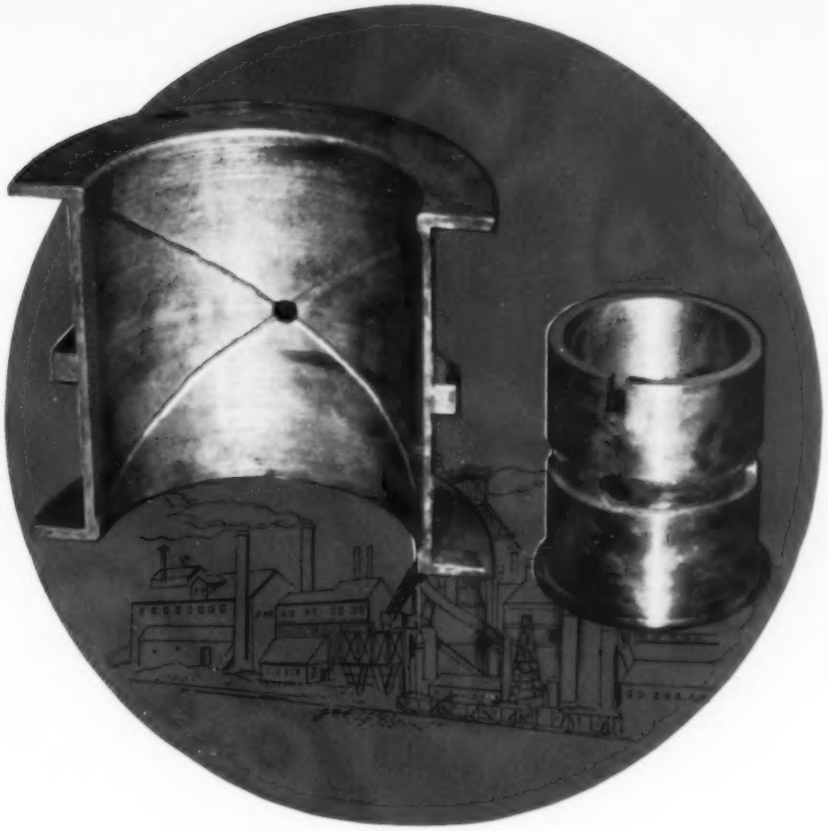

PRODUCED: BEARINGS THAT LAST 3 TIMES LONGER

An example showing how National Bearing Division has helped lick costly maintenance problems

AIR that's laden with dust and scale can be rough on bearings—as a large Midwest steel plant found out with an average of just 2 months' service on bearings in charging car wheels and edgers. Replacement labor and expense were going way out of line, when National Bearing Division stepped into the picture.

Our engineers made a special study of this mill's problem. As a result of this study they recommended a hydraulic bronze, both for its superior anti-frictional qualities and its high abrasion-resistance. Special methods of alloying and pouring, developed through N-B-M metallurgical research, insured sounder and denser castings of this bronze—further increasing its resistance to wear and abrasion.

Result? These bearings last 3 times as long as the bronze formerly used! Replacement labor and expense took a nosedive.

This actual example of how National Bearing Division saved money for a customer proves two important points: *first*, that N-B-M has the facilities for thorough research on proper alloying, and *second*, that we have the engineering skill to apply the fruits of this research to our customer's problems on . .

Non-Ferrous Bearings and Castings—
As-Cast or Machined

Bronze Bars—
As-Cast or Machined; Cored, Solid, Hexagon

Babbitt Metals—
For every type of bearing service

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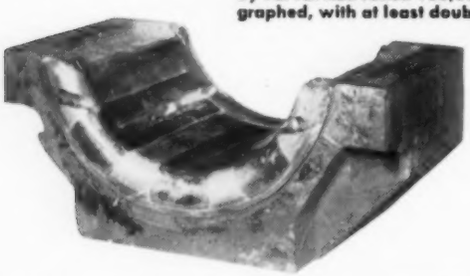
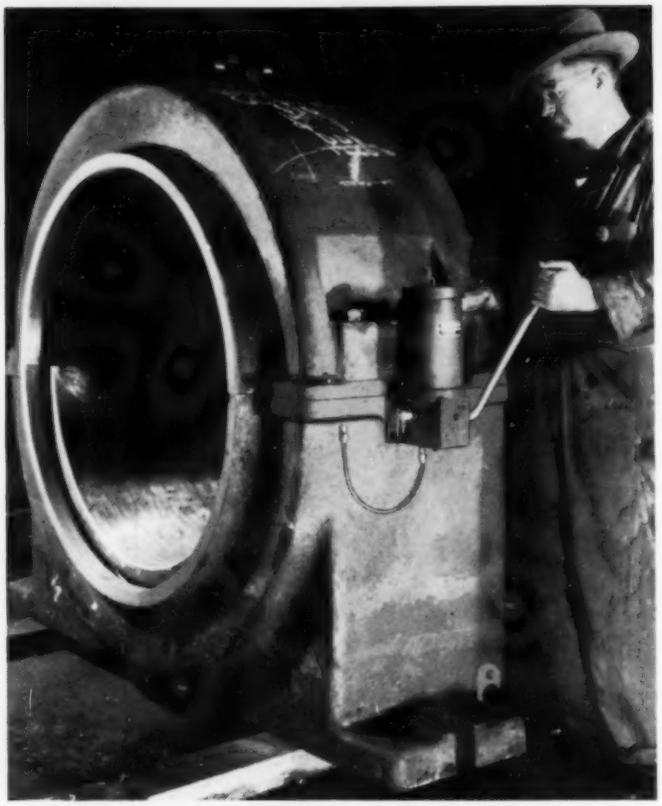
FARVAL

the efficient, economical system for lubricating plain bearings

This bearing from a sheet bar mill lubricated by Farval had rolled 135,000 tons when photographed, with at least double this life expected.





Before starting the grinding mill on which this huge bearing is installed, friction is minimized by floating the mill in oil, delivered to the bearing under pressure by a Farval pump.

• The proven method of introducing and maintaining a satisfactory film of lubricant in plain bearings is with Farval Centralized Lubrication. In case after case, facts and figures demonstrate the efficiency and economy of the Farval Dualine System.

For example, on the 3-Hi plate mill shown below, top bearing life was increased 25 times through installation of a Farval system. Top brasses formerly averaged 20,000 tons; with centralized lubrication they average 500,000 tons. Life of the bottom brasses has also been greatly extended, in spite of the continuous presence of scale. As a set of 4 brasses weighs 2,400 pounds, increased life meant a saving of more than 19 tons of bearing metal for the tonnage rolled—estimated conservatively at $15,000 saving per year.

Other savings on this particular mill, directly attributable to the installation of Farval, include reduced mill delays, reduced rejections of improperly rolled plates, reduced power costs, elimination of waste of lubricant and substantial saving of oiling labor.

There are literally thousands of Farval systems in use on plain bearings of steel mill equipment—installed during the past 25 years and operating today as efficiently and economically as on the day they were put into service.

Write for a copy of "Farval in Steel" for the whole story. The Farval Corporation, 3278 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

For 10 years a Farval manual system has protected the bearings of this armor plate leveller. In one minute, one man accurately lubricates all 22 bearings —with never a bearing missed and never any excess lubricant to drop onto plates.

Farval was installed on this 3-Hi plate mill, discussed in the text above, after it had been in service for a number of years. An original investment of only a few thousand dollars in a centralized lubrication system resulted in mill operating savings of more than $500.00 per day.

DUST, FUME AND SMOKE SUPPRESSION

By AUBREY J. GRINDLE
Vice President and Consulting Engineer*
Whiting Corp.
Harvey, Ill.

. . . . prevention of air pollution is a problem which legislation is forcing on the engineer for solution . . . .

▲ THE dust, fume, and smoke nuisance is mentioned so far back as the year 1257 when it is reported that Queen Eleanor, wife of Henry the Third, left the town of Nottingham, England, because she considered the smoke caused by the burning of "sea coals" unhealthy. A few years later in 1273, the burning of coal was prohibited, but its use continued even after a royal proclamation was issued in 1306 and one man was reported tried, condemned to death and executed.

In spite of the laws against smoke, the burning of fuel necessarily continued and the more industrialized we became, the greater became the dust, fume, and smoke nuisance. City and county ordinances have been in effect for many years in the larger localities where the amount of smoke has been measured by the Ringlemann chart. Today these ordinances are rapidly being revised to include a limit on the emission of particulate matter, and in some cases, on the emission of fumes. More complicated test procedures are now required to determine whether or not a stack or process is in violation of a code.

In the past, one important reason for building an industrial plant out in the open country was the desire of management to keep its nuisance away from the homes of its own employees as well as others, but invariably the plant was soon surrounded by homes. Today a large portion of industry has stopped fighting their neighbors and local smoke ordinances; instead they are installing or planning to install corrective equipment to stop the nuisance at its source. No longer is smoke looked upon with approval as a symbol of prosperity.

Considerable progress has been made in recent years in the burning of all fuels, but there are many processes in which high combustion efficiency does not prevent the emission of solids to the atmosphere. See Figure 1. Many of these are in the iron and steel industry and include the cupola, electric melting furnace, open hearth, blast furnace, steel converter, boilers, reverberatory furnaces, heat-treating furnaces, and ovens.

Air pollution control is a complicated and perplexing problem and is referred to in publications of all kinds throughout the United States. Volumes could be written on the problem and possible corrective methods, therefore, the author will not try to include in this paper all of the details concerning the problem and its possible solutions, but will confine his remarks to the general discussion of the subject.

Figure 1 — Smoke coming from cupola at light-up time. These sights are becoming extinct in all industry.

AIR POLLUTION CONTROL ORDINANCES

In Table I are listed several of the larger cities showing year of latest ordinance revisions, contaminants prohibited, maximum smoke opacity, etc.; all those cities having an asterisk or reference number after FA have limits on the amount of particulate matter that may be emitted. Ordinances specify "dust" or "fly ash" as particles varying from 325 mesh to 1 micron, others ignore the size of the dust and place limits on the weight that may be emitted.

There is a definite trend on the part of Air Pollution Control Authorities to revise their ordinances and restrict the emissions from stacks to a greater extent;

*Now retired from Whiting Corp. and Chief of Foundry Equipment & Supply Section and Chief of Air & Stream Pollution Control Equipment Sections of Machinery Div. of NPA.

TABLE I

CHECK LIST OF ORDINANCE PROVISIONS

(See symbol explanation at end of table)

City	Date	Air contaminants prohibited	Test method	Dense smoke standard	Fuel burning regulations			Smokeless fuel control	Boards		Rule making authority
					Installation	Inspection	Sales reports		Appeal	Advisory	
Akron	1949	DS FA (8) F	TM	R3	....	.....	....	.....	Yes 9	Yes 9	Yes
Atlanta	1941 A	DS FA (2)	....	R3	Yes	Annual	Yes	.....	Yes 3	Yes 13	....
Baltimore	1939	DS FA (6)	TM	R2	Yes	Annual	Yes	User-Sales	Yes 5	Yes 5	Yes
Birmingham	1947	DS	....	R3	Yes	.....	....	User	Yes 5	....	....
Boston	1947	DS FA	....	R3	....	.....	....	.....	....	....	....
Buffalo	1947	DS FA F	....	R3	Yes	Annual	Yes	User-Sales	....	....	....
Camden	1948	DS FA F	....	R2	Yes	Annual	Yes	User	Yes	....	....
Chattanooga	1946	DS FA F	....	R2	Yes	Annual	....	.....	Yes 5	....	....
Chicago	1947	DS FA F	....	R3	Yes	Annual	Yes	User-Sales	Yes 5	....	....
Cincinnati	1947	DS FA (3-7) F	....	U2	Yes	Annual	....	User-Sales	Yes 7	....	Yes
Cleveland	1947	DS FA (5) F	TM	R2	Yes	.....	....	User	Yes	Yes	Yes
Columbus	1949	DS FA (8) F	TM	R2	Yes	Annual	Yes	User-Sales	Yes 5	Yes 5	Yes
Denver	1948	DS FA F	....	R2	Yes	.....	....	User	Yes	....	Yes
Des Moines	1947	DS	....	R3	Yes	.....	....	.....	Yes	Yes 9	Yes
Detroit	1947	DS FA (4) F	TM	R2	Yes	Annual	Yes	User-Sales	Yes 5	....	Yes
Duluth	1931	DS F	....	R3	Yes	.....	....	.....	Yes 7	....	....
Erie	1948	DS FA F	....	R3	Yes	Annual	....	.....	Yes 3	Yes 9	Yes
Evansville	1949 A	DS	....	R2	Yes	.....	....	.....	Yes 12	Yes 12	Yes
Fort Wayne	1949	DS FA F	....	R2	Yes	.....	....	.....	Yes	Yes 5	Yes
Gary	1917	DS FA	....	None	....	.....	....	.....	....	....	....
Grand Rapids	1926	DS FA	....	R3	Yes	.....	....	.....	Yes 3	....	....
Harrisburg	1920 A	DS	....	R3	Yes	Periodic	....	.....	....	Yes 1	....
Hartford	1937	DS	....	R3**	Yes	.....	....	.....	....	....	....
Houston	1942	DS	....	.....	....	.....	....	User	....	....	....
Indianapolis	1948	DS FA (9) F	TM	R2	Yes	Annual	Yes	User-Sales	AB	Yes 7	Yes
Jacksonville	1945	DS FA	....	None	....	.....	....	.....	....	....	....
Jefferson City	1945	DS FA F	....	R2	Yes	Annual	....	.....	Yes 5	Yes 5	Yes
Kansas City	1948	DS FA F	....	R3	Yes	Annual	....	User	Yes 5	Yes 5	Yes
Lansing	1937	DS	....	U1	....	.....	....	.....	....	Yes 3	Yes
Long Beach	①	DS FA F	....	R2	....	.....	....	.....	....	....	....
Los Angeles City	1950	DS FA (1) F	....	R2	Yes	Periodical	....	User	Yes 3	Yes	Yes
Louisville	1949	DS FA F	....	R2	Yes	Annual	....	User-Sales	Yes 7	Yes 7	Yes
Memphis	....	DS FA F	....	R3	Yes	.....	....	User	....	....	....
Miami	1941	DS FA F	....	R3	Yes	Quarterly	....	.....	....	....	....
Milwaukee City	1948	DS FA (8) F	TM	R2	Yes	Annual	Yes	User-Sales	Yes 5	Yes 5	Yes
Minneapolis	1931	DS FA F	....	None	Yes	.....	....	User	....	....	....
Nashville	1947	DS FA (6) F	TM	R2	Yes	Annual	Yes	User-Sales	Yes 3	....	Yes
New Orleans	1934	DS	....	None	Yes	.....	....	.....	....	....	....
New York	① A	DS FA F	....	None	....	.....	....	.....	....	....	....
Newark	1938	DS FA F	....	R2	Yes	.....	....	User	Yes 3	....	Yes
Oakland	①	DS F	....	None	....	.....	....	.....	....	....	....
Omaha	1947	DS FA (8) F	TM	R2	Yes	Annual	Yes	.....	Yes 5	Yes 5	Yes
Peoria	1947	DS FA* F	....	R3	Yes	Annual	Yes	.....	Yes 5	Yes	Yes
Philadelphia	1949	DS FA (8) F	TM	R2	Yes	Periodic	....	.....	Yes 7	Yes 7	Yes
Pittsburgh	1946 A	DS FA (6) F	....	R2	Yes	Annual	Yes	User-Sales	Yes 5	....	Yes
Portland	1943 A	DS FA	....	R3**	....	.....	....	User-Sales	Yes 5	....	....
Providence	1947	DS FA * F	....	R2	Yes	Annual	Yes	Sales	Yes 5	Yes 5	Yes
Reading	1948 ②	DS FA I F	....	R2	Yes	Annual	Yes	Sales	Yes 5	Yes 5	Yes
Richmond	1947	DS FA (11)	TM	R3	Yes	.....	Yes	.....	Yes 5	Yes 7	Yes
Rochester	①	DS	....	Special	....	.....	....	.....	....	....	....
Salt Lake City	1941	DS FA F	....	R2	Yes	.....	Yes	User	....	....	....
San Diego	1937	DS FA F	....	R3**	....	.....	....	.....	....	....	....
San Francisco	①	DS FA	....	R3**	....	.....	....	.....	....	....	....
Spokane	③	DS	....	None	....	.....	....	.....	....	....	....
Springfield	③	DS	....	None	....	.....	....	.....	....	....	....
St. Louis	1948	DS FA (6) F	TM	R2	Yes	.....	Yes	User-Sales	Yes 5	....	Yes
St. Paul	1925	DS	....	R3	....	.....	....	.....	....	Yes 12	....
Syracuse	1948	DS FA (3-8) F	....	R2	Yes	.....	Yes	User-Sales	....	....	....
Tacoma	1950	DS FA (7-3) F	....	R2	Yes	.....	....	.....	Yes 5	....	....
Tampa	1943	None	....	.....	Yes	.....	....	.....	....	....	....
Toronto	1949	DS FA (3-8) F	TM	R3	Yes	Periodic	Yes	.....	Yes 7	Yes 7	Yes
Trenton	①	DS F A	....	None	....	.....	....	.....	....	....	....
Utica	....	DS FA (6)	....	R3	Yes	Periodic	....	.....	....	....	....
Wilmington	1946	DS	....	R3	....	.....	....	.....	....	....	....
Yonkers	1950	DS FA F	....	R2	Yes	.....	....	.....	....	....	....
Youngstown	1950	DS FA (6) F	TM	R2	Yes	Annual	Yes	User-Sales	Yes 7	Yes 7	Yes

SYMBOL EXPLANATIONS

Date refers to the year of adoption of the basic code or its most recent revision.

"A" Ordinances now being amended.

① Smoke regulations incorporated in city health code, date of which was not furnished.

② Proposal ordinance, not yet formally approved.

③ Smoke regulations incorporated in city fire code, undated.

"DS" in Table I refers to Dense Smoke as measured by the Ringlemann chart illustrated in Figure 1, or to the "Umbrascope" in which one thickness of 60 per cent opacity glass equals No. 1 scale, two thicknesses equals No. 2 scale, 3 thicknesses No. 3 scale, and 4 thicknesses equals No. 4 scale.

FA (—) Limits of emission of solids vary as follows:

(1) 0.2 per cent by volume SO_2.

0.4 gr/cu ft adjusted to 12 per cent CO_2 at gas temperature except that dust or fumes may not exceed amounts shown in table of ordinance varying from 0.48 per cent of the process weight at 50 lb/hr to 0.67 per cent of the process weight of 60,000 lb/hr. Maximum permitted 40 lb/hr.

(2) 90 per cent collection entering collector, minimum.

(3) 85 per cent collection entering collector, minimum.

(4) 0.3 gr/cu ft at 500 F and 50 per cent excess air.

(5) 0.425 gr/cu ft at 500 F, 50 per cent excess air. Must collect 75 per cent in equipment installed before ordinance and 85 per cent with new equipment.

(6) 0.75 gr/cu ft at 500 F and 50 per cent excess air which amount not more than 0.2 gr/cu ft shall be larger than 325 mesh, 44 microns.

(7) 0.85 lb per 1000 lb of gas — 50 per cent excess air.

(8) 0.85 lb per 1000 lb of gas adjusted to 12 per cent CO_2.

(9) 0.75 gr/cu ft at 500 F, 50 per cent excess air of which not more than 0.2 gr/cu ft at 850 F shall be larger than 325 mesh.

(10) 0.85 lb per 1000 lb of gas containing 50 per cent excess air. Maximum 0.5 lb per 1000 lb of gas shall be larger than 325 mesh.

(11) 2 lb per 1000 lb of gases at 12 per cent CO_2 — must collect 75 per cent.

Various city ordinances define particulate matter as follows:

Cinders: Particles not ordinarily considered fly ash or dust because of their greater size, entrained in the products of combustion and consisting essentially of fused ash and/or unburned combustibles.

Dust and Fly Ash: Gas-borne or air-borne particles larger than one micron (approximately 0.00004 in.); two cities specify above 10 microns.

"F" — Fumes: Gases, vapors, metallic oxides that are of such character as to create an unclean, destructive, offensive or unhealthful condition.

* These codes limit the emissions, amounts unknown to the author.

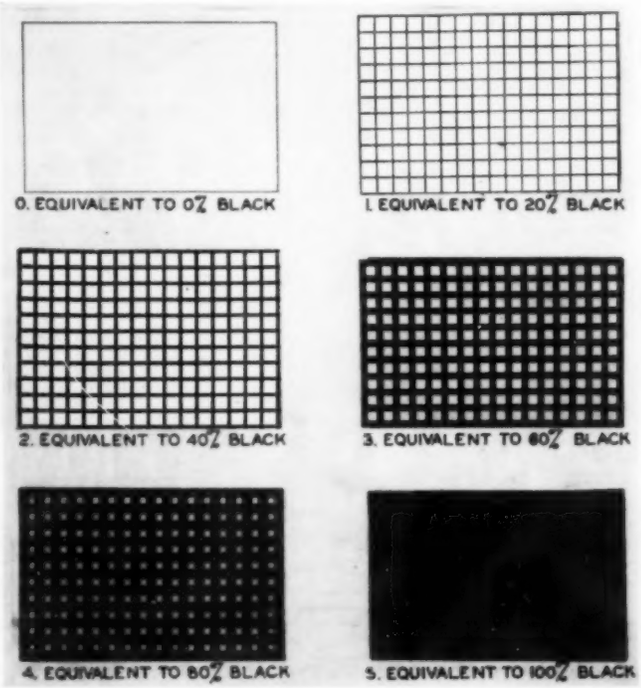
** Greater than.

"TM" in Table I refers to Test Method specified. All those so marked use the American Society of Mechanical Engineers test code. Those not marked will apparently accept any recognized or accurate method.

several large cities are in process of amending their ordinances and others that have not had control laws are now providing them. In addition to the restrictions on opacity measured by the Ringlemann chart, more cities now have laws controlling the emissions of particulate matter and fumes, especially sulphur compounds. There is a definite trend to legislate against the use of high volatile fuel unless it is burned smokelessly by pulverization or by stokers, and then the fly ash must be collected to prevent a dust nuisance.

The ASME test code for dust emission is now the most widely used test method; however, others are used and acceptable in some cities. There is a great need for a practical instrument that will traverse the stack, automatically adjust the velocity in the sampling tube to the stack gas velocity, and at the same time secure an accurate dust sample and a volume record of the escaping gases at the same time the dust sample is taken. Instrument engineers are working on this problem and if it can be solved, the cost of testing various types of equipment will be greatly reduced.

Figure 2 — Ringlemann's scale for grading the density of smoke.


0. EQUIVALENT TO 0% BLACK
1. EQUIVALENT TO 20% BLACK
2. EQUIVALENT TO 40% BLACK
3. EQUIVALENT TO 60% BLACK
4. EQUIVALENT TO 80% BLACK
5. EQUIVALENT TO 100% BLACK

A figure entered after "yes" in the Boards' column indicates the number of members. Where no figures are shown, the governing ordinance does not fix a definite number of appeal or advisory board members. The omission of an entry for a particular city in one or more columns is to be interpreted as meaning that the ordinance contains no such provisions.

NEW CODE FOR BOILER EMISSIONS

A proposed standard for regulating the emission of solids from boiler plant chimneys was presented to the annual meeting of the Air Pollution and Smoke Prevention Association of America at Montreal on May 25, 1950. This standard provides for maximum quantities of solids emissions in pounds per hour on a sliding scale ranging from 22 lb/hr for 10,000 lb of steam generated per hour (about 2 per cent of coal fired) to 3200 lb/hr for 4,000,000 lb of steam generated per hour (about 7/10 per cent of coal fired). This proposed standard was developed after three years' work of the committee and may be included in many future city ordinances.

This is the second indication that the trend in future air pollution control ordinances is toward specifying the allowable emissions on the basis of per cent of process weight.

VARIABLE LOCAL FACTORS

No two cities are exactly alike with respect to various phases of the smoke, dust, and fume problem. In the south and west coast states, boiler heating plants and other processes, where gas is available for fuel and the heating loads are light, do not create the problems that other districts have. However, as industry moves into these areas, there are bound to be some processes that require solid fuels for lowest cost and highest efficiency; other processes will present a dust and fume problem if corrective equipment is not installed.

Topography, climate, type, location, and extent of industrial activity are the important items. Hills and wind velocity affect the rate at which air-borne particles settle to the ground. Relative humidity and barometric conditions also have a great affect upon the intensity of air pollution.

Thus, one city cannot adopt the ordinance of another without first making sure that the conditions in both are substantially alike.

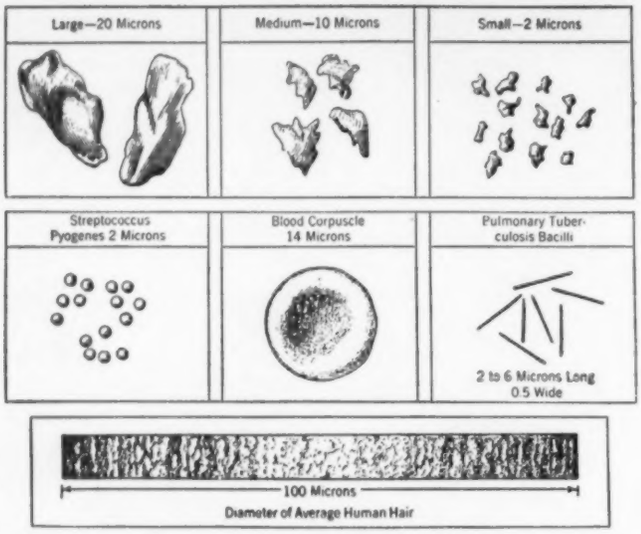


Figure 3 — Sketches illustrate various sizes of dust particles carried in atmosphere.

Possible repetition of the damage caused by air pollution at Donora, Pa., is pointed out by authorities. In addition to the 20 deaths resulting from the smog of 1948, the real market value of Donora property dropped more than 9 per cent in 1949, a decrease of over $3,000,000 although property throughout the state showed an increased market value.

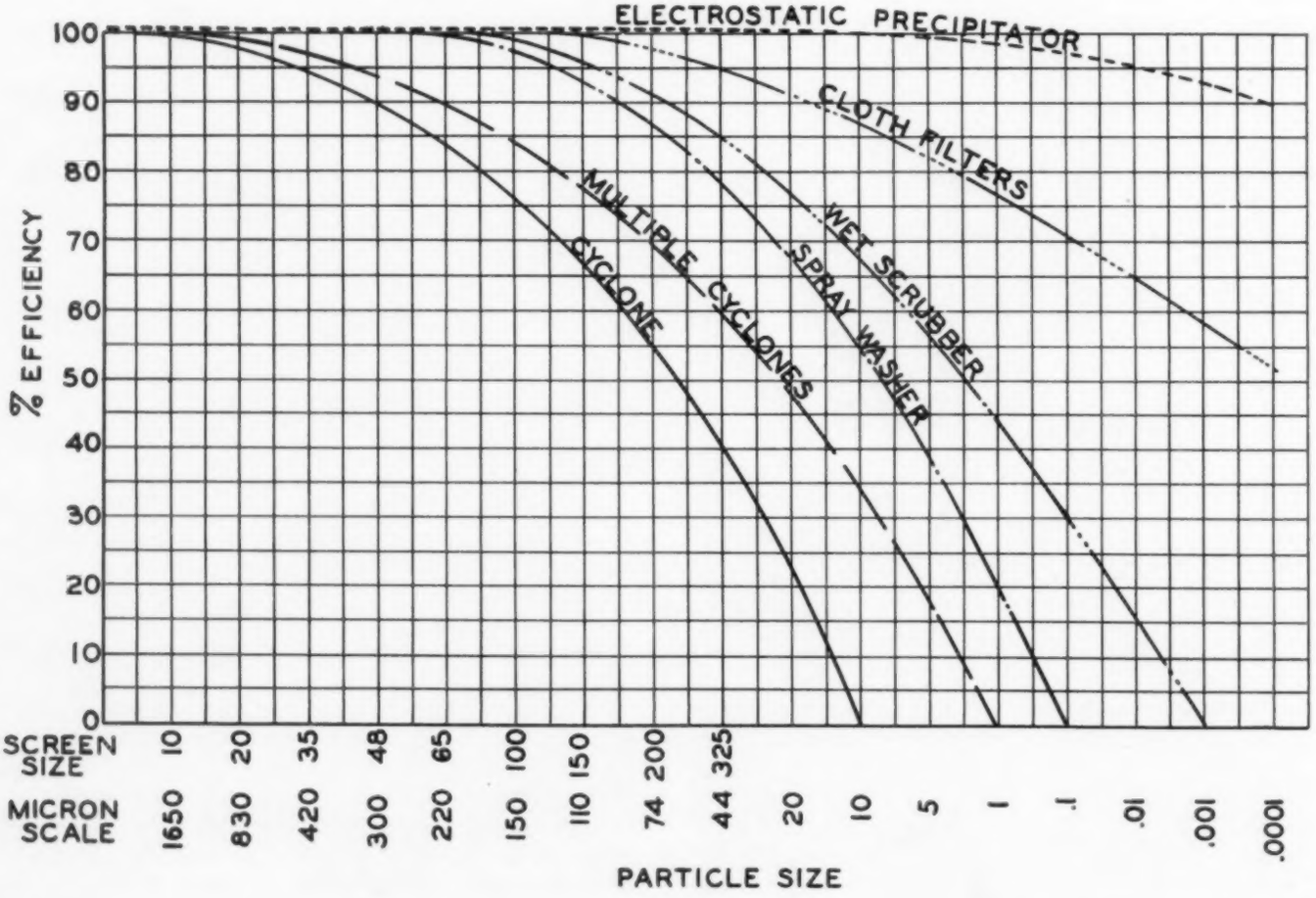
Many people associated with industry have criticized the very stringent air pollution ordinance of Los Angeles County, but anyone who spends a little time there is soon convinced that the laws are justified if industrial plants are to be allowed to expand and increase in number. This code does place a hardship on the company which has to spend large sums of money to correct its nuisance or cease operations. Los Angeles County is on relatively level ground at low altitude, and there is not enough wind to blow the contaminated air west over the mountains and rain seldom occurs to act as a natural purifier as it does in other parts of the country.

UNITED STATES TECHNICAL CONFERENCE

The recent United States Technical Conference on Air Pollution was attended by 762 representatives of industry, manufacturers of corrective equipment, health and enforcement authorities, scientists, legislators and engineers. This conference brought out many interesting facts and is bound to have its effect on future air pollution control ordinances.

At this conference, there were seven simultaneous panels in session for two days, May 3 and 4, 1950, Approximately 98 written and oral discussions were presented on the effects of air pollution on agriculture and health; analytical methods; corrective equipment; instrumentation, legislation, and meteorology.

Figure 4 — Comparative approximate efficiency of various types of dust suppression equipment for various particle sizes and average specific gravity.



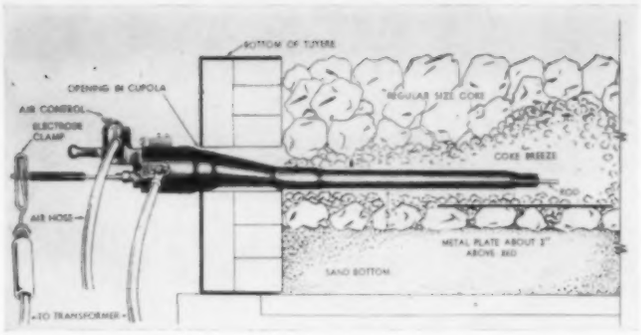


Figure 5 — The coke igniter prevents wood smoke and pays for itself out of savings.

There was considerable discussion at this conference concerning the advisability of passing federal laws because aerosols travel from one state to another; one air pollution control official from England claimed that they had by analysis traced dust which settled in London to the United States. Because of the varying conditions existing in the various communities, most local authorities believe that regulations should be localized to the cities or counties with state enabling acts to legalize the local laws. The federal government could play a helpful role by helping in research through the Bureau of Mines.

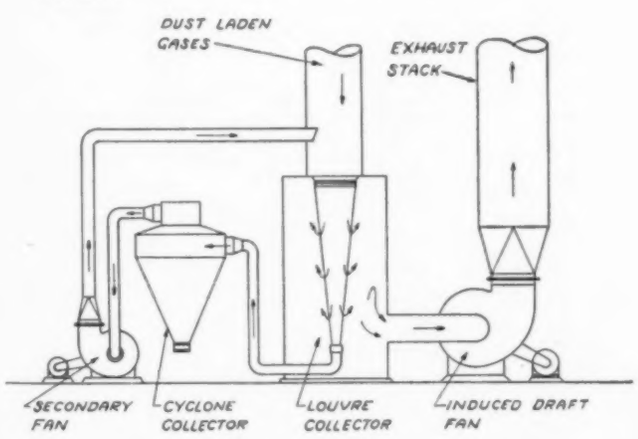
Although Donora and Los Angeles are exceptional examples of extreme conditions, there is undoubtedly much truth in the many claims of the great damage caused by air pollutants to health, vegetation, and property; therefore, without going into the various ramifications of the damages caused by air pollution, let us study what can be done about it.

THE PROBLEM

Even though the equipment industry has made much progress in the development and application of corrective equipment in recent years, there is much more to be done, in order that control equipment may be produced that is economically feasible for the average industrial plant.

We must agree that high stacks or plants built or moved to the open country are not the answer; instead, we must reduce the amount of smoke, dust, and fumes escaping to the atmosphere either inside or outside the buildings to a minimum.

Figure 6 — Combination louver and cyclone collection system.



Smoke caused by inefficient combustion in these modern times is definitely a waste and can be corrected by methods known to most engineers. High volatile coals can be burned in pulverized form or by stokers with practically no carbon monoxide or black smoke leaving the stack. High efficiency oil burners are available from several manufacturers, and the plant that is lucky enough to have a supply of reasonably priced natural or producer gas has no serious problem in preventing smoke.

Fly ash, dust and fumes are our major present-day problems and with the enactment of ordinances permitting only the emission of low percentages of the process weight, we have to provide corrective equipment that will collect substantial amounts of the sub-micron material, heretofore considered unimportant. The ordinances that permit the emission of large percentages of 325 mesh (44 micron) dust particles, but limit the total amount that may be emitted to fractions of grains per cubic foot or fractions of pounds per 1000 lb of gas, are confusing the problem. Large percentages of the particulate matter escaping to the atmosphere are under 1 micron in many processes. Therefore, the equipment manufacturers will be wise to design for, first, burning the carbon monoxide (CO) in the escaping gas; and, second, for the collection of sub-micron particles.

Figure 3 is submitted to illustrate the size of a micron. One micron is 0.01 the diameter of an average human hair and a large proportion of the dust going into the atmosphere is composed of sub-micron material and amounts to a surprisingly high total weight per hour or per cubic foot of stack gas.

The problems on iron-melting cupolas are similar in many ways to other processes in the iron and steel industry. In these processes, stack emissions contain varying percentages of carbon, silicon, iron, sodium, iron oxide, manganese, calcium, silica, sulphur, and other metallic and non-metallic constituents. Particle size varies with the process and depends to a great extent on the amount of fuel ash contained in the dust. Typical sizes of particles emitted from stacks vary as follows:

0—10 microns	30 to 97 per cent
10—20 microns	0 to 20 per cent
20—40 microns	0 to 20 per cent
44 and larger	0 to 60 per cent

Grain loading of gases in various combustion and metallurgical processes are as high as 15 grains per cu ft of gas and amounts in some instances to 3 per cent of the process weight. Dust loading of the gas is affected by the velocity, specific gravity of particulate matter, operating rate of the process and type of fuel used.

The specific gravity of dust particles from metallurgical and combustion processes varies from 1.30 to 7.50.

The temperature at the top of the stack or gas outlet will vary from 100 F on an electric melting furnace during the melting period to 2000 F at the top of a short inefficiently operated cupola.

The sulphur (SO_2) in the escaping gas from fuel-fired metallurgical processes ranges in the neighborhood of 0.004 per cent by volume and is only considered a

nuisance when there is a temperature inversion causing a concentration of these fumes at ground level.

The gas analysis from various combustion and metallurgical processes ranges from 0 to 13 per cent CO, 0 to 20 per cent CO_2, and 0 to 16 per cent O_2. The ferrous iron melting cupola at its best operating efficiency operates with a non-oxidizing atmosphere below the charging door and at this point is comparable to the blast furnace. This carbon monoxide gas should be burned before allowing it to escape to the atmosphere and can be utilized to heat the combustion air. This method of operation, when employed, results in a minimum of smoke; lower fuel consumption; less oxidation of metal; greater process capacity; safer operation and an easier dust suppression problem.

EFFICIENCIES OF AVAILABLE EQUIPMENT

The illustrations on the following pages are presented to give a general idea of the principles employed in dust suppression equipment now available. No attempt is made to point out the advantages or disadvantages of the various makes of equipment. This can be obtained from the manufacturers. In this paper the author attempts only to present the average efficiency of the different types of equipment.

Various types of equipment have been developed or are in process of development; each type has its most effective applications as may be judged from studying Figure 4.

This chart is produced to give a comparative idea of the efficiency of various types of equipment. It must be remembered in studying the chart that there are many makes of the different types of equipment with widely varying efficiencies.

When considering efficiencies of collectors, we must know what we are going to collect. For instance, if you were going to confine chickens, a good high chicken wire fence would be 100 per cent efficient but how efficient would it be against mosquitos?

A simple cyclone is usually suitable for collecting wood shavings or sawdust. When we have finer particles, we must employ a more efficient type of dust suppressor. There are so many types of dust with varying analysis, and specific gravity, that it is not practical to go into the various aspects here. Particulate matter that is easy to wet or that will settle readily in water may be most economically collected with a wet type of collector even though the particles are very small; but as the dust becomes more difficult to wet because of its analysis, temperature, or size, and the specific gravity becomes less, the problem becomes more involved.

In recent extensive tests on the West Coast where several attempts have been made to supply equipment that will meet the Los Angeles code on foundry cupolas, all equipment has failed to date except cloth filters and electrostatic precipitators.

Until the present Los Angeles ordinance was passed, and numerous tests were made on stack emissions, industry including the suppressor manufacturers did not realize the large percentage of sub-micron particles that were contained in the exhaust gases. This fine particulate matter is composed of the difficult solids to collect and was the principal reason for the non-compliance of most of the equipment tested.

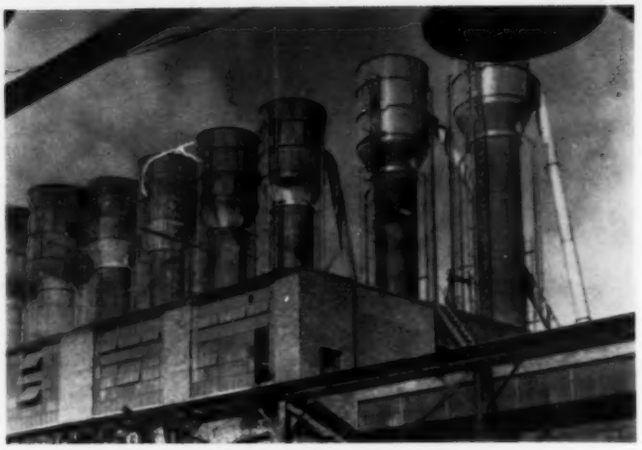
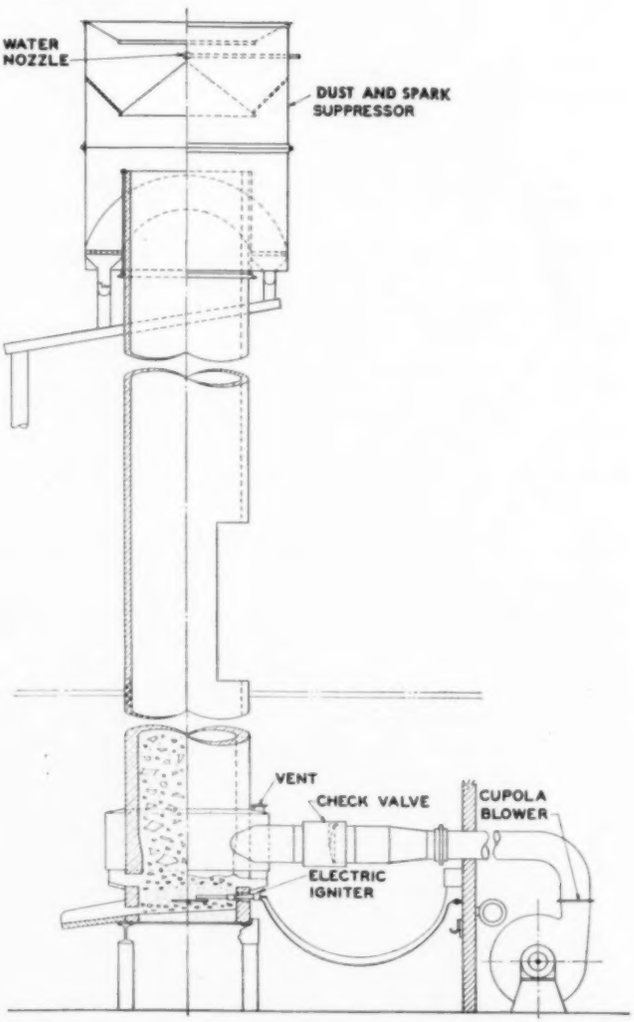


Figure 7 — These eight stacks are equipped with spray washers.

WOOD SMOKE

Wood should not be used for lighting a fire in any combustion process because of the odorous, eye smarting smoke created; gas, oil, or electricity can be used for this purpose, usually at a saving. A recent development

Figure 8 — A spray washer is used on cupola stack and coke igniter.



(Figure 5) is the electric coke igniter which ignites cupolas and similar processes quicker, without smoke and with other advantages.

THE DRY CYCLONE

The dry cyclone is the least expensive dust collector available, but is only satisfactory on large particles, when used in a vented closed system, or where the specific gravity of the dust is sufficiently high to permit the required collection. A large diameter cyclone on stack gas will collect between 10 and 25 per cent of the solids.

THE MULTIPLE HIGH-VELOCITY CYCLONE, CENTRIFUGAL COLLECTOR, LOUVER AND DRY SKIMMER COLLECTORS

These collectors (Figure 6) are designed to produce a high velocity action within the collector for the purpose of throwing the dust out of suspension. Multiple units are usually required in order to handle the volume of gas or air. Various arrangements are employed in this type of equipment, including center tubes, louvers, and double cones. This type of equipment will connect between 20 and 60 per cent of the solids contained in stack gases.

THE SPRAY WASHER

There are many designs of spray type washers. See Figures 7, 8, and 9. They are placed at the top of the stack or after a downcomer leading from the stack to the collector; they cool and wash the gas at the same time. Sulphur and condensation are the main problems; however, with proper design the condensation problem is minor and the sulphuric acid created by absorption of sulphur in the gases is minimized by the use of a neutralizing agent such as soda ash.

A good design of spray washer is quite efficient on fly ash particles over 5 microns, but very inefficient on the sub-micron sizes. The efficiency on stack gas dust will range from 40 to 70 per cent.

WET SCRUBBERS

These suppressors (Figure 10) contain various principles, all have some means of imparting a centrifugal action to the dust particles or a means of bubbling them through water. This type of suppressor will collect more of the sub-micron material due to its more effective wetting ability. They use various types of spray nozzles, venturi tubes, and eliminator plates are seldom used on stack gases. They are between 30 and 75 per cent efficient when used on stack gas. Until recently, most of these suppressors have been used to collect the dust produced inside the plants by grinders, shakeouts, drying process, etc. The same sulphur problem exists with this as with all other types of wet suppressors and has the added expense of power for an exhauster over the washer placed on top of the stack.

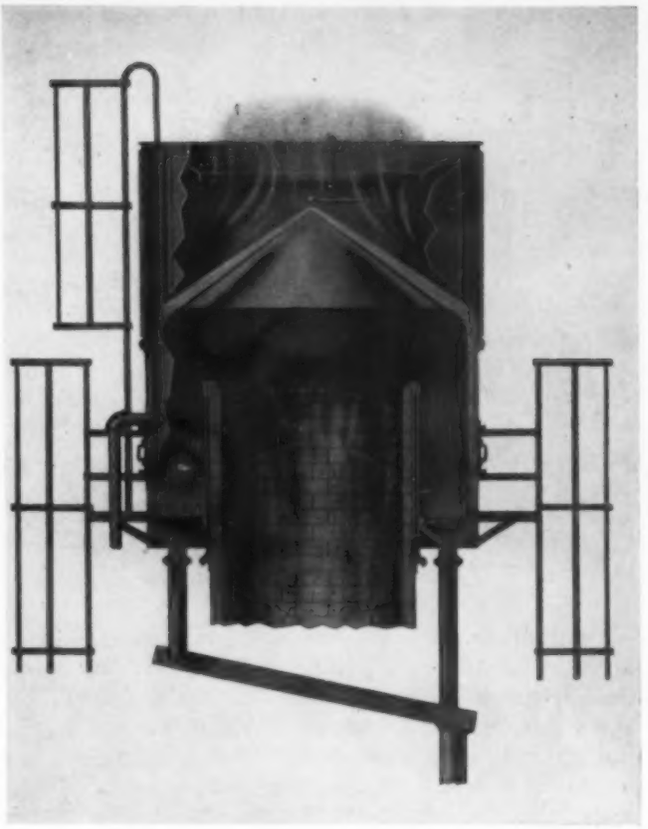


Figure 9 — The stack gas spray washer cools as it cleans.

Figure 10 — Cross-sectional view shows suppressor with an automatic ejector tank. The nozzle in the central axial tube assures even distribution of the water through the disintegration section.

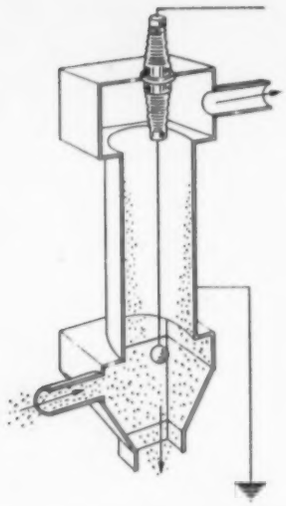


Figure 11 — Sketch shows electrostatic precipitation principle.

CLOTH FILTERS

Cloth filters are usually of two types, bags or screens and have until recently been used only for collecting dust from cool, dry processes. With the demand for stack gas cleaners of higher efficiency on sub-micron dust, this type of equipment is being redesigned and improved to handle higher temperatures and corrosive materials. The new glass cloth and other new fabrics are being used with considerable success, and they promise to be the solution to the problem encountered when trying to use the cloth filter for correcting the nuisance caused by dust in hot stack gases. These collectors are collecting up to 95 per cent of the escaping particulate matter. The only question not yet answered is the cost of maintenance. This appears to be reasonable, after being under test for the past eight months without fiber fracture or other excessive damage, and arresting dust from up to 500 F stack gas.

ELECTROSTATIC PRECIPITATOR

This is by far the most efficient dust collecting method known at the present time and is also the highest priced equipment. See Figure 11. The maintenance cost compares favorably to other efficient collectors, and is just as effective on sub-micron particles as it is on dust above 325 mesh or 44 microns. Collecting efficiencies depend to a great extent on the velocity and temperature of gas passing through the collector, but a good design will range from 90 to 98 per cent collection of stack gas dust.

FUTURE EQUIPMENT DESIGN

As air pollution control ordinances continue to become more stringent, lower-cost, more highly efficient suppression equipment will have to be provided. This is a challenge to the dust suppression equipment manufacturers and they will need the full cooperation of the manufacturers of process equipment. The author predicts that within 25 years the tall smoke stack will be outmoded. In its place we will have waste heat recovery equipment, at the discharge of which there will be very little smoke, and the dust and fume suppressors will be so efficient that an exhaust pipe out through the roof will be sufficient to carry away the relatively clean process waste.

Because of the growing necessity for clean stacks, better metallurgical control and mechanization, small metallurgical plants are being replaced by much larger plants where the installation of the required equipment can be justified.

Smoke commissioners in some of the large cities make the claim that industry creates only about 20 per cent of the dust, smoke, and fume nuisance and that homes, automobiles, incinerators, and other private sources create the 80 per cent. If this is true, we may expect more restrictive ordinances governing the pollutants attributed to individuals after industry has made more progress.

Many homes now burn oil, gas, anthracite coal, coke and bituminous coal in stokers and smokeless domestic furnaces and boilers without smoke. Pulverized coal domestic heating systems have been developed that are smokeless. Dust is the final problem here as it is in industry, therefore, it is quite probable that within the near future, a simple, low-cost dust suppressor will be developed for domestic use probably of the electrostatic precipitation type.

DISCUSSION

PRESENTED BY

A. H. ARBOGAST, Engineer of Combustion, Bethlehem Steel Co., Bethlehem, Pa.

AUBREY J. GRINDLE, *Vice President and Consulting Engineer, Whiting Corp., Harvey, Ill.

M. J. CONWAY, Consulting Fuel Engineer, Gap, Pa.

E. C. McDONALD, Combustion Engineer, Republic Steel Corp., Cleveland, Ohio.

F. E. KLING, Tenafly, N. J.

* At time of paper presentation.

A. H. Arbogast: Because of our rapidly increasing population and the liberal swing of our various governments, national, state, and municipal, controls of every kind have become a universal panacea, because in the eye of the average taxpayer, all that is required to correct any pollution problem is to establish standards and enact laws to enforce these standards.

While the control of stack emissions or smoke resulting from the incomplete combustion of high volatile fuels has been satisfactorily solved after years of investigation and research, we still have many problems involving process dusts, fumes, mists and gases which are much more difficult to control. Some of these problems will require many years for satisfactory solution rather than the twenty-five years which Mr. Grindle so optimistically forecasts.

The check list of ordinance provisions presented provides us with valuable data and illustrates the widening scope of legislation in the field of air pollution control.

We agree that future equipment design is a challenge

to dust suppression equipment manufacturers. At the same time we trust that these new developments will proceed hand in hand with increased collection efficiencies and more reasonable installation, operation and maintenance costs.

I believe the application of woven glass fabrics has opened one of the most fertile fields of gas filtration or dust collection methods yet investigated because it provides efficient dust separation at operating stack temperatures. However, like all filtering processes, it is complicated by the problem of high pressure differentials.

Air and stream pollution abatement are parallel problems, but when water is used for gas scrubbers or stack sprays, these two problems unite. I would appreciate if Mr. Grindle will acknowledge this complication and give us a brief introduction to its consideration.

Aubrey J. Grindle: I may be a little over-optimistic on this twenty-five year question. We may not be doing too much about this smoke problem if we get into a real war. On stream pollution; it is going to be out of the question to put scrubbers on any type of dust collecting equipment and let the waste water run into a stream. That is one of the main problems in wet washing of gases.

If we have a sulphur problem, that would corrode metal. It must be made out of something that will stand corrosion and even then a certain amount of soda ash or neutralizer must be used in the water and for that reason, I believe, large installations particularly are going to be going to electrostatic precipitators. If glass cloth filters work out, they may be a cheaper solution for smaller applications.

M. J. Conway: Primarily, Mr. Grindle's paper is related to atmosphere pollution, and as such, the author has collected a great deal of information of value to the Association's reference files.

The time is past when we should treat this subject in whispers behind closed doors. The sooner we take the public into our confidence and let them know we are working on preventive measures, but that we also have our problems, so aptly described by Mr. Grindle, the sooner we will have more uniform ordinances restricting the distribution out into city and country side, dust and other contaminants which, to say the least, do not constitute good neighborly behavior.

The steel industry has had dust elimination problems for years and undoubtedly does more gas cleaning in cfm at standard conditions than any other industry, when considering both coke oven gas and blast furnace gas.

This gas cleaning, of necessity, must be done within much cleaner limits than those given in the Check List of Ordinance Provisions, Table I of Mr. Grindle's paper, and is done chiefly by three methods, or a combination of two or more of them — cyclones, wet washers and electrostatic precipitators.

I know it would have been difficult for Mr. Grindle to have rated the various types of cleaners under the several classifications he used. However, he does state that certain wet scrubbers are not more than 75 per cent efficient, when used on stack gases. This statement may be misinterpreted if applied to engineered gas cleaning in general, as there are wet scrubbers available which, when properly applied, will remove 99 per cent of the dust in gases, consistently delivering exit gas dust loadings not exceeding 0.01 grains per cu ft, with no dust particles exceeding 0.4 microns.

Aubrey J. Grindle: I think that might be true. There are many scrubbers on the market. The reason that I used seventy-five per cent, is because that seems to be the limit of the average scrubber. There are some scrubbers that have collected ninety-five per cent, but the steam consumption that was used on these and the power consumption seemed to be out of the question. We ruled them out. If there are any wet scrubbers that will do a good job up to ninety-nine per cent or even ninety per cent on hot gases, under even 350 F, we have a market for them. I would like to know more about them.

E. C. McDonald: You did not mention anything about ultrasonic. Is that something that can be counted upon in the future?

Aubrey J. Grindle: Yes, I checked the manufacturers. It does look promising. So far there is nothing definite enough for me to mention in this paper. I think there is a possibility on certain types of dust.

F. E. Kling: Have you tried asbestos cloths as a filter?

Aubrey J. Grindle: I have not heard of any tests on asbestos cloth. I have heard of tests on nylon, or various nylon synthetic fabrics. It seems they are going for nylon or nylon fabrics. Asbestos might work. I do not know if it will stand the moisture.

F. E. Kling: I made tests for the duration of a year six years ago with asbestos bags, as described in an article in "Blast Furnace and Steel Plant," October 1946, titled "Dry-Hot Cleaning of Blast Furnace Gas." The average results of 195 tests indicated an efficiency of 99.9 per cent, dust content of gas entering the filter was 2.82 grains per cu ft gas and that of the clean gas 0.001 grain. The pressure drop was 6.5 in. water gage.

Asbestos filter bags have been used in the non-ferrous industries for some time where higher temperatures are encountered than cotton cloth can stand. The difficulties experienced, however, were the short life of the bags caused by wrinkling, and high stresses at the point of suspension during the shaking period. I overcame this deficiency by clamping the bag onto a wire frame which keeps the bag taut and transmits the shaking vibrations to the bag at a number of points instead of just at the top.

Aubrey J. Grindle: I think that is very interesting, you have probably been ahead of the times. Has your filter been used commercially?

F. E. Kling: It has not been used commercially because of the inertia with which new ideas are taken up and also, the electric precipitator had made considerable headway, even though it is a much more complicated and costly apparatus both in installation and operation. The gas has to be washed and cooled to a temperature of about 90 F, then the dust has to be removed from the washwater and finally the water has to be separated from the sludge. With a filter, the operation is reduced to only one step, and the sensible heat of the gas is saved.

Aubury J. Grindle: What do you do with the dust at the bottom of the bags?

F. E. Kling: Blow it back into the blast furnace at several points above the mantle, which is being done

in Europe. The dust is collected in a tank with a conical bottom and the opening at the top closed when filled. Then blast furnace gas, compressed to 80 psi is admitted and the dust forced through a 1½ or 2-in. pipe at the lower end of the cone to the furnace.

Aubrey J. Grindle: You are liable to suspend it!

F. E. Kling: No, the compressed gas keeps it moving.

Member: It is very important to take into consideration all the variations in topography — valleys, hills and the weather conditions. They all play a very important part in air pollution.

It seems to me that we have written-off high stacks a little too quickly as a means of handling some of the air pollution. One non-ferrous company, for a great many years has used that method of taking care of their high sulphur gases from out of their smelters in the west. They have stacks over six hundred feet high, and they are building them higher where they are running into fume gases. Out there, they find that the dispersion of these high stacks give a low enough concentration, so that they do not have any difficulty. In steel plants, where you are running into higher sulphur with your coal — that may turn out to be a problem that we will all want to give a lot of consideration to.

I think that, probably, we are going to have to look at this in a little different way, because when you stop to think of the large particles and their relative weight, and how many fine particles, with their relative weight that are in there, and that you are perhaps taking out ninety per cent, you may be throwing out fifteen times as many particles in the fine parts as in the heavy part. You have to take into consideration the particle size distribution as well as the efficiency and weight of the particles that are taken out.

One of the things that is commanding a lot of attention right now is the question of how much dirt can be dumped out into the air. There are a large number of plants in certain locations that have various cleaning equipment and they find that the volumes of gas that they are putting through their stacks, even high stacks, with their consequent efficiency, that the concentration of dust which is being dumped out on the country side is high.

There is supposed to be a meeting very soon and the subject which they will discuss is how big a plant should be before it becomes a nuisance to the community. In other words, how many tons of ash is it possible to disburse from a single plant area and not be a nuisance to the community?

Of course, there are a lot of questions there. I do know we do not have the answers for them, but we do have to take them into consideration. The public is becoming interested in their solution. The more we tell the public about it, the more they appreciate the problem. For example, one of the questions is: "who is going to pay the cost for cleaning the air." The companies will at first, but they are not the only people who are going to pay. The public is going to pay, and if we can educate the people to understand that they are the ones who are going to pay for this clean air, then they are going to be a little more reasonable in what they are asking for.

AISE VISITS ALAN WOOD STEEL CO.

On Tuesday May 22, 1951, The Alan Wood Steel Co. acted as host for an inspection trip of the Philadelphia district section of The Association of Iron & Steel Engineers through the plant at Ivy Rock, Swedeland, and Conshohocken, Pa. Three hundred fifty-five guests made the trip through the plant, and enjoyed the lunch provided by the company as shown in the illustration. Of particular interest was the 30-in. hot strip mill, which went into operation about a year ago. This plant was covered by a special section writeup in the May 1951 Iron and Steel Engineer and copies of this section were distributed on the trip.

TRANSFORMER OIL IN THE STEEL PLANT

By JOHN F. BOAL
Lubrication Engineer
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. . . . adoption of a regular testing and reconditioning program for transformer oils can keep the oil in good condition and reduce maintenance costs . . . .

▲ ALTERNATING current generators first appeared as a major source of electrical power in steel plants near the beginning of the present century and simultaneously transformers were installed as a vital part of the transmission system for the distribution and utilization of this power.

Many of these original transformers are still in service in steel plants today. They are characterized by an open type construction, little attempt being made to prevent air, moisture or dust from entering the transformer tank. See Figure 1. After these units had been in operation for a time, it was found that the entrance of these extraneous materials adversely affected the insulating quality of the transformer oil and caused other changes in the oil which rendered it less effective as a cooling and protective medium for the transformer windings and core. During subsequent years, numerous improvements were made in transformer design, important among which were various provisions for protecting the oil from contact with air, moisture and other deleterious external materials.

One of the first steps in this direction was the introduction of the outdoor type transformer, in which the transformer tank was provided with tightly fitted and gasketed covers, doors and bushings. This restricted the flow of air over the surface of the oil and reduced the entrance of entrained dust and moisture. The only opening from the interior of the transformer tank was a rain proof breather pipe which permitted a flow of air in and out of the tank to compensate for changes in temperature of the oil or air. This is called the free breathing type of transformer. A large number of the transformers in service in steel plants today are of this type. (Figure 2.)

Because preservation of the oil in good condition was still a major problem, further steps were taken in later designs to prevent contact of air with the hot oil inside the transformer. Development of the conservator type transformer was an important step in this direction. The conservator is a small tank placed above, and connected with, the main transformer tank. See Figure 3. The transformer is completely filled and the oil level brought up into the conservator tank, thereby presenting a small surface of oil to the air and keeping the exposed oil at a lower temperature than that in the main tank. With this design, condensation is reduced and entrance of moisture into the main tank is minimized. The result is a reduced rate of oxidation and much longer useful life of the oil.

In the free-breathing type of transformer, moisture may be almost completely removed from the air entering the breather pipe by attaching to it a container filled with hygroscopic material such as calcium chloride. Activated alumina, because of its moisture adsorbing ability, also may be used for this purpose. It is necessary

Figure 1 — This open type transformer installed in 1906, is rated at 150 kva, 6.6 kv.

*At time of paper presentation, now United States Steel Co.

to renew all of these drying agents periodically in order to maintain effective moisture removal. Removal of oxygen from air entering the breather cannot be effected by absorption, as in the case of moisture, because there is not available a suitable absorbing material for oxygen that would give reasonably long service before requiring replacement.

A number of other methods are used for restricting or entirely eliminating the passage of air in and out of transformers. One of these, used particularly on very large transformers, is blanketing the surface of the oil with an inert gas such as nitrogen, a tank of the compressed gas and a pressure regulator being utilized to maintain a slight positive pressure inside the transformer tank. For some installations, hermetically sealed transformers are used, in which case the problem of excluding air and moisture from the oil is entirely eliminated.

Accompanying the development of the various methods for excluding air from the transformer oil, improved methods for cooling transformers have been applied, resulting in lower oil temperatures and longer oil life.

TRANSFORMER OIL PROBLEMS

Mineral oil of low viscosity has been the fluid most widely used for filling transformers. It is particularly suited for this purpose because it provides good insulation and protection to the windings and also, circulating by convection, carries away the heat developed in the core and windings when the transformer is under load. Because of its inflammability, however, steel plants have adopted a non-inflammable fluid for certain of their transformers in those locations where elimination of the fire hazard justifies the considerably higher prices commanded by these latter fluids.

Transformer oil supplied today by most refiners is an improved material over that available for use in the early transformers. While transformers were being developed in which more and more protection was provided for the oil, the refiners have developed oils with greater oxidation resistance and various other improved characteristics. Steel plants now buy oil to fairly well standardized specifications from transformer manufacturers or directly from refiners. The following specification is typical for transformer oil:

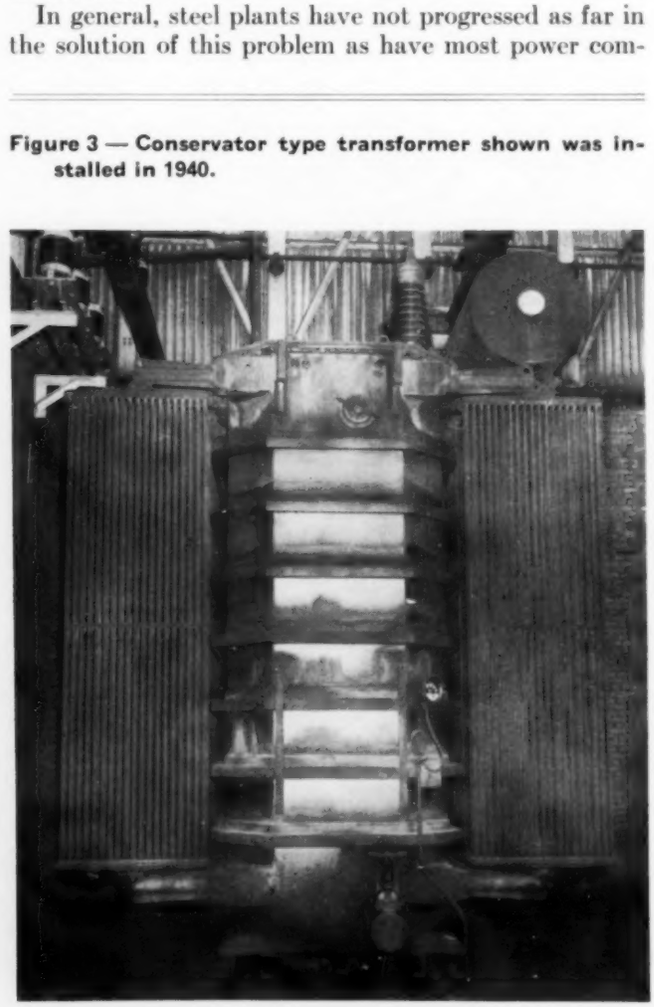
Specific gravity	0.89
Viscosity, SSU (100 F)	60
Flash point (F), min	275
Pour point (F)	—50
Neutralization No., max	0.08
Sulphur	0
Dielectric strength, min	22 kv

A problem of concern to many steel plant operators is that of maintaining transformer oil in a satisfactory condition to insure against failure of the transformer and possible loss of steel production. The problem of transformer oil maintenance has received considerable study in recent years by power companies, and certain industries which have many large transformers in service and a number of them have adopted systematic procedures for testing and maintaining their transformer oils.

In general, steel plants have not progressed as far in the solution of this problem as have most power com-

Figure 2 — Free breathing outdoor type transformers shown are rated at 1500 kva, 6.6 kv each, and were installed in 1925.

Figure 3 — Conservator type transformer shown was installed in 1940.



panies. There are several reasons for this. Among them are the relatively few transformer failures in steel plants that are attributed to the conditions of the oil, the smaller amount of transformer oil in service as compared to that used by power companies, the difficulty steel plant operators have had in obtaining a reasonably accurate picture of the condition of the oil in their transformers, and lack of information as to the best methods to use in maintaining or reconditioning the oil in a particular steel plant.

NEED FOR TRANSFORMER OIL MAINTENANCE PROGRAM

A logical question which presents itself to the operators of a steel plant is whether or not there is need for a maintenance program for the transformer oils in their plant. A typical integrated steel plant consisting of blast furnaces, open hearth furnaces, primary and finishing mills and generating most of its own power, may have at least 100,000 gal of oil in service in transformers. The transformers will vary widely in age and in design. In some, the oil is still relatively new but in many, it has been in service from ten to thirty or more years.

It has been the general practice in many steel plants to make periodic checks on the dielectric strength of the oil in the transformers, and to centrifuge or filter through a blotter press any oils found to be low in dielectric. Except in a few plants, it has not been considered necessary to go beyond this step in determining the suitability of the oil for continued service. An increasing amount of attention now is being given to another condition of the oil, that is, the extent to which it has become oxidized in service, with formation of acid materials and sludge deposits inside the transformer. A survey of the condition of the transformer oil in steel plants that do not have a regular maintenance program for their transformer oils often will show that there is a relatively large amount of acid materials and sludge in many of the transformers (Figure 4). If sludge deposits are permitted to continue to build up, eventually they will restrict the flow of oil through the radiators, reduce heat transfer from the core to the oil, and may make possible a failure of the windings through overheating. Also, there is evidence to indicate that acidic material in oxidized oil may slowly deteriorate the insulating varnish on the core windings, eventually causing a failure of the transformer. Therefore, from the standpoint of good preventive maintenance, it is logical to take steps to prevent the formation of excessive acids and sludge deposits in the transformers and to remove, to the extent that is practicable, any of these materials that have already formed.

TESTS FOR USED TRANSFORMER OILS

As a first step in a preventive maintenance program, it is necessary to adopt a method of periodically testing the transformer oil to determine its condition and its suitability for continued service, or its need for treatment of some type. There are several different viewpoints concerning the relative value of the various tests that may be made on used transformer oil to determine its suitability for continued use. The following group of six tests is now being used by some steel plants which have recently adopted a regular testing program.

1. Dielectric strength.
2. Viscosity, SSU at 100 F.
3. Neutralization number.
4. Interfacial number.
5. Color.
6. Sediment (naphtha insoluble).

These tests can all be made from a quart sample of oil taken from the transformer, and the average steel plant laboratory can perform the tests.

These tests, and their individual significance, are discussed below.

1. *Dielectric Strength* — This test is made on a kv tester, designed especially for use on insulating oils, and the dielectric breakdown point is determined. If a low dielectric (below 18 kv) is obtained, another sample should be secured from the transformer since it is possible the first sample received moisture from an external source, giving an erroneous low dielectric value. A low result on the dielectric strength test indicates the presence of moisture in the transformer oil.

2. *Viscosity, SSU at 100 F.* — This is the ASTM standard Saybolt viscosity test. Although a single viscosity test on a transformer oil is of little significance, a progressive increase in test results over a period of time is indicative that oxidation of the oil is taking place. This viscosity increase is usually more noticeable in the older more oxidized oils. In recent years new transformer oil has had a viscosity of 55 to 60 seconds, but some of the earlier oils varied considerably, often ranging between 50 and 120 seconds.

Figure 4 — Core removed from tank of transformer shows sludge deposits.

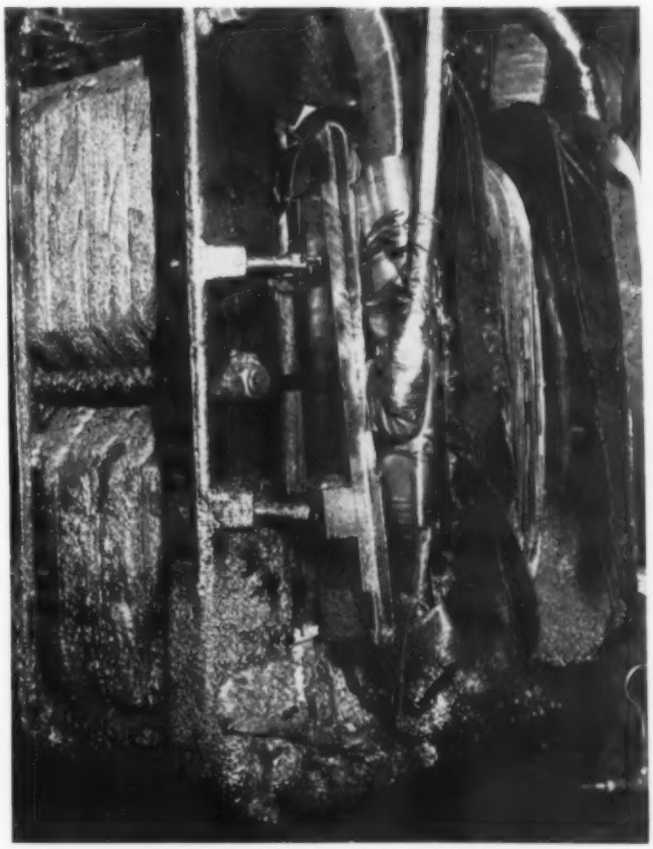


TABLE I

TEST DATA ON TEN USED TRANSFORMER OILS, WITH RECOMMENDED TREATMENT

Sample No.	Transformer		Oil		Dielectric strength kilovolts	Viscosity SSU @ 100 F	Neutralization number	Interfacial tension	Color tag ASTM	Sludge in sample	Recommended treatment
	Rating kva	Years service	Capacity gallons	Years service							
1	15,000	10	5,175	3	30	58.0	0.08	28.6	1	No	None
2	833	5	554	5	30	62.6	0.17	20.0	1.5	No	None
3	1,500	6	739	6	29	57.4	0.17	26.4	1	No	None
4	1,000	13	892	13	28	71.0	0.28	19.3	4	No	None
5	150	13	225	13	30	58.4	0.47	15.6	4	No	Fullers e arth filter
6	1,500	25	1,460	25	29	53.4	0.84	18.0	4.5	Yes	Fullers earth filter
7	800	32	1,215	32	24	54.8	1.15	11.6	4.5	Yes	Fullers earth filter
8	1,000	33	800	33	28	55.2	1.10	13.8	5	Yes	Fullers earth filter
9	150	44	200	No record	28.5	99.0	2.30	11.7	8	Yes	Change oil
10	150	44	200	No record	26	111.0	2.80	10.9	8	Yes	Change oil

3. *Neutralization number* — This is an ASTM test, the neutralization number being defined as the number of milligrams of potassium hydroxide required to neutralize the acid in one gram of oil. This test measures the total amount of acid and other materials in the oil that will react with potassium hydroxide. It indicates the extent to which oxidation of the oil has taken place.

4. *Interfacial tension* — This is a simple test made with a Du Nouy tensiometer. The test measures the force in dynes necessary to pull a platinum ring through the interface between water and a sample of the transformer oil. This force is highest with new oil and decreases as the oil becomes oxidized. The test indicates the extent to which oxidation of the oil has progressed, it being considered more sensitive than the neutralization number for this purpose, particularly in the earlier stages of oxidation.

5. *Color* — This is an ASTM test that rates the oil from 1 to 8 on the basis of its color, the higher numbers corresponding to the darker oils. As oil oxidizes it normally becomes darker in color, however, a dark color also may be caused by contamination from bushing material or some other foreign substance, or it may indicate the presence of colloidal carbon.

6. *Sediment (naptha insoluble)* — The approximate percentage of sediment in the oil may be determined by diluting the oil with naptha and centrifuging, the percentage being read on a graduated tube. If sludge has developed in a transformer, this test usually will indicate its presence. However, it is not an accurate measure of the sludge present, because most of the sludge normally settles out of the oil and deposits between the windings or on the bottom of the transformer tank.

ANALYSIS OF TRANSFORMER OIL TESTS

After these tests have been made and the results tabulated, an analysis of the results will give an approximate picture of the oil in each transformer, as shown in Table I. The following guiding principles may be followed in making the analysis:

1. A value of less than 18,000 volts for the dielectric strength indicates the oil contains excessive moisture. Removal of the moisture from the oil by some method is recommended.
2. The remaining five tests, viscosity, neutralization number, interfacial tension, color and sediment, all indicate the extent to which oxidation of the oil has taken place. The following tabulation shows the usual range of values for each of these tests on typical new and oil, badly oxidized oil.

Test	*New oil*	*Old oil*
Viscosity, SSU at 100 F	55 to 60	60 to 120
Neutralization number	0.05	0.7 to 2.0
Interfacial tension	30 to 40	10 to 18
Color	Less than 1	6 to 7
Sediment, per cent	0	0.2

No one of these tests alone is significant in determining the condition of the oil. They should be considered collectively in deciding whether the oil is suitable for continued service in its present condition, whether treatment is necessary for restoration of its properties, or whether it should be completely replaced. The neutralization number and interfacial tension are generally used as the yardstick for judging the oil. It has been found by several investigators that, in most cases, sludging of the used oil does not begin until the neutralization number has risen to 0.6 or higher and the interfacial tension has fallen to 18 dynes or lower. If the oil has been exposed to considerable moisture during its service, sludging may begin before these values are reached. If an oil has not exceeded the above figures in these two tests, and if the color and sediment are low in value, the oil can be considered in suitable condition for further use, without treatment. If the oil has deteriorated beyond the above figures, treatment with fullers earth can be used to return the oil to a satisfactory quality level for continued use. See Figure 5. This treatment will also improve the color of the oil,

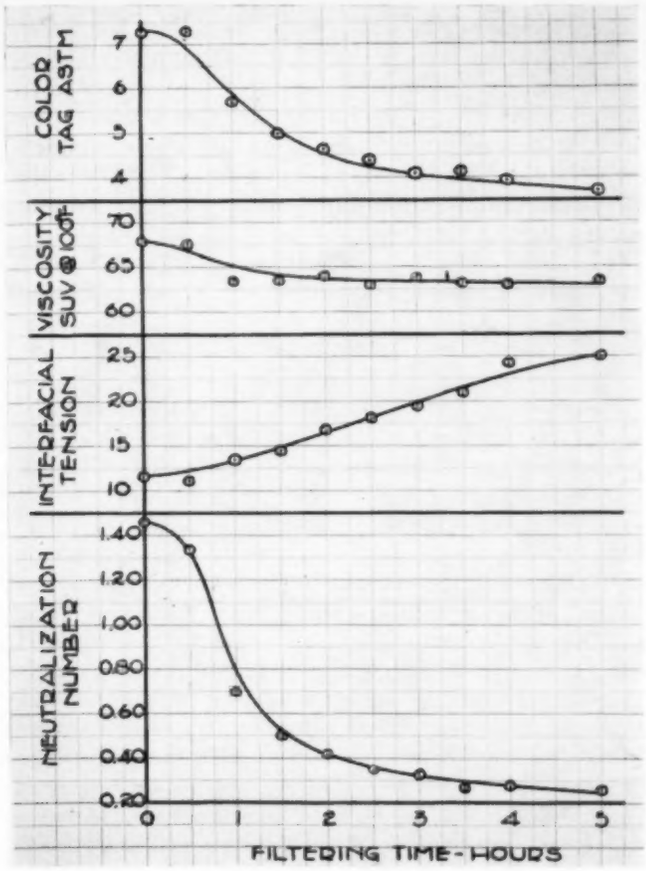


Figure 5 — Curves show improvement in a used transformer oil by circulation through a portable fullers earth filter.

remove moisture, colloidal carbon and other solids.

A plant desiring to institute a maintenance program for its transformer oils should give first attention to those oils which are in the worst condition, as indicated by these tests.

There are other tests, such as power factor, steam emulsion number and analysis of the sludge, which also have value in indicating something of the condition, or the cause of a certain condition, of the transformer oil. Like the previous tests mentioned, however, these tests are of greatest value when their results are considered in conjunction with several of the other tests. The power factor test is made with special electrical testing equipment and a number of steel plants are using this test to gain information on the overall performance of a transformer, including the oil.

EQUIPMENT FOR RECONDITIONING TRANSFORMER OIL

Equipment for reconditioning used transformer oil may be classified under two general headings. One is equipment intended primarily for removal of moisture from the oil so as to maintain a satisfactory dielectric strength; the other is equipment whose primary purpose is the removal of acids and other oxidation products from the oil so as to extend its useful service life and retard sludge formation. There is some overlapping of these functions in certain equipment of each type. For adequate maintenance of their transformer oils, a steel plant should have one of each of these two general types of equipment.

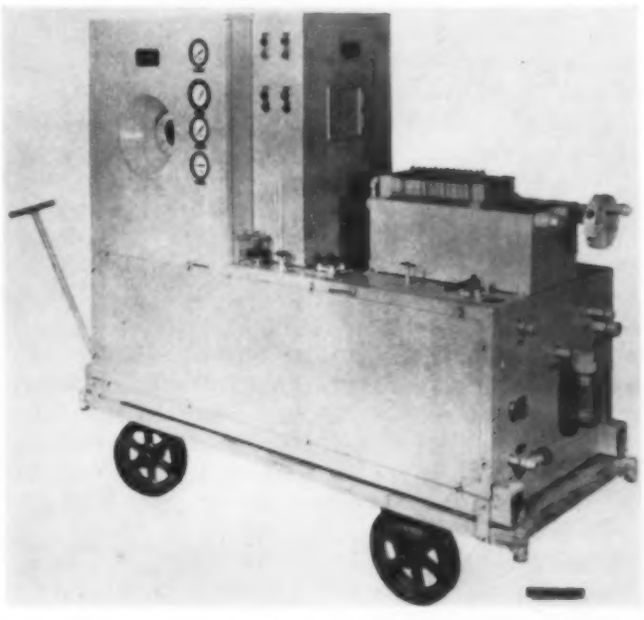
Removal of moisture from the oil can be accomplished satisfactorily by use of the blotter press, the centrifuge, or by a vacuum dehydration unit. The blotter press has been widely used on transformer oil in steel plants for moisture removal on both newly installed oil and periodically on the oil which has been in transformers in service, when dielectric strength tests indicated the need for it. For effective operation, the blotter paper should be dry, a special drying oven often being used for this purpose and the oil temperature should not be higher than absolutely necessary. A case was experienced wherein new oil installed in a new transformer gave a low dielectric strength reading. After several days of circulating the oil through a blotter press, during which time the oil temperature was elevated by an impedance load, the dielectric strength of the oil had improved very little. The oil temperature was then lowered, and on continuing the circulation through the blotter press the dielectric strength quickly rose to an acceptable value, permitting the transformer to be put in service.

The centrifuge is used to some extent for moisture removal and both it and the blotter press will remove any solids, except very finely divided and colloidal materials that may be in suspension in the oil.

In the usual vacuum dehydration unit (Figure 6), oil coming from the transformer is filtered through a cellulose cartridge or blotter type filter to remove solids. The oil is preheated to 130 F and pumped through spray nozzles into a chamber in which a vacuum of approximately 29 in. of mercury is maintained by means of a vacuum pump. The moisture flashes off, leaving the oil in a dry condition. This unit also removes from the oil some of the lower boiling point fractions of any acidic materials that may be present in the used oil.

All of these three types of equipment can be obtained as portable units which may be connected directly to

Figure 6 — Portable vacuum dehydration unit is used for removing moisture and low boiling oxidation products from used transformer oil.



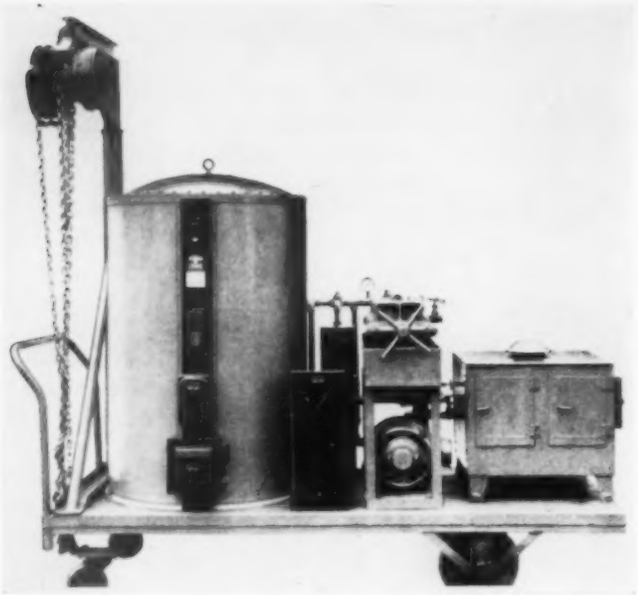


Figure 7 — Portable fullers earth filter has hoist for changing earth. A blotter press is also included with this unit.

the transformer, oil being taken from a valve at the bottom of the transformer tank and returned through a connection at the top of the tank.

For the removal of oxidation products from the oil, additional equipment is necessary in which an adsorbent material such as fullers earth or activated alumina is utilized. Use of these adsorbents very effectively restores the oil to an almost new condition. Fullers earth has been the adsorbent material most widely used in steel plants for reconditioning of transformer, as well as other types of oil.

There are three general methods in use for using an adsorbent material to recondition transformer oil.

One method is the removal of the oil from the transformer into drums and transporting it to a conveniently located stationary filtration unit. This unit may consist simply of an open top, elevated tank, partly filled with adsorbent material into which the oil may be poured and allowed to percolate through the material. The restored oil is kept in drums for further use in transformers. There are also more elaborate types of stationary equipment available, some of which combine vacuum dehydration with adsorbent treatment.

Another method is to utilize a portable unit containing the adsorbent filtering material (Figure 7). This unit is connected directly to the transformer, the oil is circulated through it, and returned to the transformer until the desired oil characteristics are obtained. The charge of adsorbent material in this filter may have to be changed one or more times during filtration depending upon the size of the filter, the number of gallons of oil in the transformer and the extent to which the oil has become oxidized. This method has the advantage that filtration may be carried out with the transformer under load. This is important in steel plants where standby transformers usually are not provided and where certain transformers cannot be taken out of service without loss of production.

A third method, used to some extent, is that of equipping a transformer with a thermosyphon. This arrangement consists of a small tank filled with adsorbent material mounted on the outside of the transformer. Piping connects this tank to the top and bottom of the transformer tank. The normal heating of the oil in the transformer causes a flow by convection slowly through the adsorbent tank were oxidation products are removed from the oil. It is necessary to replace the adsorbent material from time to time, usually every one or two years. Successful use of the thermosyphon is limited to transformers containing new oil or oil which has been reclaimed by one of the other adsorbent methods.

FULLERS EARTH TREATMENT FOR USED OILS

The fullers earth adsorbent treatment is very effective in restoring the properties of oxidized oil. This is demonstrated by Figure 5 which shows the improvement effected in treating 300 gallons of used oil in a 200 kva lighting transformer by five hours of circulation through a portable fullers earth filter, a sample of the oil being taken every half hour during the filtration. It was necessary to add 125 gallons of new oil in the beginning to fill the filter, but most of this oil was recovered from the filter at the end and stored in drums for use in filling the filter prior to use on the next transformer. The filter contained 400 pounds of fullers earth. An examination of this chart shows a continued improvement in color, interfacial tension and neutralization number throughout the filtration. It is inadvisable to attempt to restore oil entirely to the same characteristics as new oil, because it involves uneconomical use of adsorbent and overtreatment with earth is likely to decrease the resistance of the oil to oxidation during future service. The neutralization number may be used as a control, the filtration continuing until the neutralization number falls to approximately 0.2.

FACTORS AFFECTING COST OF FULLERS EARTH TREATMENT

The cost of fullers earth treatment per gallon of oil treated varies widely depending upon several factors. One of these is the amount of oxidation products present in the oil which determines the quantity of earth required for removal of these products. Again using neutralization number as a measure of the oxidation products in the oil, reduction of the neutralization number from 1.0 to 0.2 requires approximately 1.5 pounds of fullers earth per gallon of oil treated.

The size of the fullers earth charge in the filter relative to the gallons of oil in the transformer is important in considering the labor cost of treating the oil. Changing of the earth is time consuming; therefore, a large size filter containing at least 400 pounds of earth, while somewhat higher in first cost, will usually prove to be the most economical for steel plant use. Other costs to be considered in connection with the filtering are attendant labor, transportation of the filter and fullers earth to and from the site of the transformer, and the value of the oil discarded with the spent earth.

Taking all costs into consideration, the total cost per gallon still is usually less than the cost of new oil.

Further, the cost of reconditioning the transformer oil by this method is often much more than offset by the benefit gained in being able to treat the oil with the transformer still in service.

SLUDGE REMOVAL FROM TRANSFORMERS

If sludge develops in a transformer it settles out of the oil, coats the core, windings and exposed parts of the tank; consequently, any attempt to remove the sludge by circulating the oil through a filter is generally ineffective. Under these conditions it is usually necessary to open the transformer, remove the core and wash the sludge from the windings by pumping a stream of oil over them. This requires taking the transformer out of service, considerable expense in opening the transformer and removal of the core, and, therefore, this is a situation to be avoided, if possible. Thus, prevention of sludge is the principal justification for establishing a regular program of maintaining the oil.

RECORDS

A complete transformer oil maintenance program should include a well kept record of the condition of the oil in each transformer. Oil samples for testing should be taken from each transformer yearly, and the complete results recorded, preferably on a separate card for each transformer. Any filtering or treating of the oil should also be recorded on the card. Plotting of the test data obtained each year is advantageous as it permits any sharp changes in the condition of the oil to be observed readily.

INHIBITORS FOR TRANSFORMER OIL

A recent development that is receiving increasing attention by operators of transformers is the use of oxidation inhibitors in the transformer oil. Accelerated oxidation tests carried out in the laboratory have indicated that the useful life of transformer oil may be extended several times by this means. The inhibitor may be added to new transformer oil or to used transformer oil which has been reconditioned by fullers earth treatment.

This development furnishes an added incentive for steel plant operators to institute a maintenance program involving fullers earth treatment of their used transformer oils since, in the past, there has always been the question of what life could be realized from a reconditioned oil.

The material most widely used as a transformer oil inhibitor has been di-tert-butyl-para-cresol. Tests indicate that this material gives satisfactory performance in mixed transformer oils and has other desirable characteristics such as being insoluble in water and it does not produce solid oxidation products which would precipitate. It is not removed from the oil by fullers earth treatment.

By adopting a regular testing and reconditioning program for their transformer oils, steel plants can keep the oil in a good operating condition, transformer difficulties will decrease, and overall maintenance costs should be reduced. With improvements in transformer design to give greater protection to the oil and through the availability of improved types of transformer oils, there should be a trend toward a decrease in the problem of oil maintenance in the future.

DISCUSSION

PRESENTED BY

C. E. PRITCHARD, Chief Lubrication Engineer, Republic Steel Corp., Cleveland, Ohio.

W. A. SMILEY, Electrical Engineer, Bethlehem Steel Co., Steelton, Pa.

GEORGE DAVIS, Lubrication Engineer, Shell Oil Co., Pittsburgh, Pa.

C. E. Pritchard: The author has given a very comprehensive review of not only the life history of transformers as associated with the steel industry, but also the effect of programs introduced by those responsible for the continuous rehabilitation of the transformer oil to obtain extended service life.

One point, which we feel is quite important, is the effect of contamination by the residual oxidized materials that are left in transformers, even where the rehabilitation or reconditioning programs have been in vogue.

We have noted that a relatively small percentage of the highly acidic material, in the form of oil bearing sludge, has been found to be quite potent from the standpoint of promoting oxidation deterioration of the oil. As little as one-half of one per cent to two per cent of contaminants has effectively reduced the service life of the oil to a marked degree. This then introduces the need for consideration of a means whereby this potent material might be eliminated in a feasible manner.

Some work has been performed in this direction on the basis of setting up a flushing program with a solvent material which would effectively remove this residue, generally of resinous nature, and by so doing come up with a counterpart or a parallel to the experience gained in the turbine field.

It is a program that still is in its infancy but it is believed that it will prove to be of importance to us in the future, and should be given due consideration.

The justification for consideration of the solvent cleaning program is the expense involved of taking the transformer out of service, removing the core from the transformer body, and then resorting to the normal procedure of alkaline cleaning.

He did point out that we have several available methods of reconditioning oil. Some of them are found to be more effective than others. All of those which are effective demand very diligent care on the part of the operators performing such functions if satisfactory results are to be forthcoming. Quite often you perform the function of bringing the oil back to a seemingly good or new condition by removing the heavy solids, the moisture contaminant, and also the more potent acidic materials; but you have not removed the intermediary or the secondary products of oxidation. By not removing these secondary products, you will find that they in turn will propagate the chain reaction of oil deterioration which gradually progresses to a point where the oil is unfit for service operations. It does

bring to mind the need for a definite program of control, as pointed out by Mr. Boal, for religiously examining, on a periodic cycle, those conditions that surround the formation of such deterioration products.

He mentioned the usage of inhibited transformer oils. It is felt that if you can start out with a new unit, or an old unit that has been effectively cleaned and use a transformer oil properly inhibited against oxidation, you will very definitely minimize the development of these sludge materials which result in the acidic build-up or degradation of the oil itself.

We have a lot to learn in this direction also, but based on our experience in the turbine field, it is believed personally, that we should take the cleaning program into consideration. This then will provide a practice that will minimize the tendency for oil deterioration taking place at any time, and that can only come from starting with a clean system.

I want to re-emphasize the word "clean system." Just recovering or reclaiming the oil, we feel is not enough. Consideration must be given to ensure elimination of the residual sludge that remains around the core windings which provides an active catalyst in the presence of metals, and propagates the oil deterioration chain reaction. Unless proper precautions are taken in this regard severe damage to the core windings may be encountered.

W. A. Smiley: In many ways, the steel mill engineer is faced with a more delicate and complex problem than that which confronts the public utility engineer. Most of the steel plants have grown little by little, with the result that we have transformers of all makes, styles and vintages. In the steel plant with which I am associated, we have remaining eighteen out of an original thirty-three transformers of the type shown. See Figure 1. These transformers went into service in 1901 or 1902.

When we recently took nine of these units out of service for reconditioning, we found them in the condition shown by Figure 4. To make matters worse, we also found that after thorough cleaning and replacement of the old oil by new oil, the new oil went "bad" in about sixty days.

The case of this type transformer is made of lead coated sheets which are sealed to the lead coated structural members by a cast joint of lead solder. The combined catalytic action of lead, copper and iron, together with the contamination by residual oil-sludge and acid, caused extremely rapid deterioration of the new oil.

In our thinking in regard to transformer oils, it is possible to become very confused unless we recognize and accept the fact that each transformer is a separate entity. As I have mentioned, the case lining, or absence of lining, must be considered; the degree of sealing of the case must not be overlooked; and the kind of oil, or in most instances, mixture of oils should be determined.

In order to reduce maintenance, it is usually possible to suitably coat the case interior to prevent contact of oil and case, but we have no such recourse for the copper winding and steel core.

The case can be hermetically sealed by welding, or be suitably gasketed and a manometer seal applied so as to prevent access of moisture and oxygen. The gasket seal does not prevent inflow or outflow of gases, as those of you who have used nitrogen protection on transformers know.

In regard to oil, I noticed that Mr. Boal did not give the usual over-emphasis to neutralization No., as the criterion by which oil is to be judged. The fact that some acids are corrosive and some are preservative, and that neutralization No. determines their sum, constitutes a real problem. We have been working on pH (hydrogen ion concentration) as a possible indication of the presence of the corrosive group.

It might be worthwhile to mention that the centrifuge will not remove that water which is in solution in the oil. This fact was brought out in a paper, presented by a centrifuge maker, before the AISE several years ago. See "Centrifugal Purification of Oils in Steel Plants," by Charles M. Ambler, 1949 Proceedings of the Association of Iron and Steel Engineers, p 356.

Various users have found that the vacuum dehydration unit will not only remove water and volatile acids, but from some kinds of oil it will remove about one-half of the heavy non-volatile acids. It was a matter of considerable surprise to us when we first encountered oils of this kind. However, it has come to our attention that others have observed the same phenomenon. So far as we now know, this kind of oil has not been investigated sufficiently that we are able to identify it prior to treatment.

The thermosiphon type of treatment, although used for over fifteen years with marked success, seems to be receiving too scant consideration. This may be because it is regarded as a maintenance measure rather than as a remedial treatment.

When we first investigated the technical phase of the transformer oil problem, we set up a thermosiphon type element, an oil heater and a pump on a small transformer which had burned out due to sludge accumulation. Care was taken so that sludge lying in and upon the core and coils would not be disturbed by oil circulation.

A short time after operation was started, the neutralization No. of the oil was reduced from 1.20 to that of new oil, and the color was reduced from No. 6 to No. 2. However, what is much more important, the sludge which was undisturbed by oil flow turbulence had passed back into solution in the oil and had been adsorbed by the alumina, so that the transformer was really clean. The experiment was continued to determine what would happen under over-treatment. We found that the oil was bleached and actually made slightly alkaline. This action should inspire caution in the use of any of the adsorbent treatments.

Rather than repeatedly meet the hazard of over-treatment, which is present in any method using an adsorbent, with the possible exception of the "batch system," the use of inhibitors seems to be indicated where the service is severe.

It would seem that, with the very low cost of the cresol type inhibitor it would be economical to protect our oils against oxygen by its use; and with the extremely low cost of vacuum dehydration, we are justified in keeping our oils dry and high in dielectric strength by periodic treatment.

In the final analysis of our transformer problem, we find at hand the technical means to solve it, and only

the economic phase of the problem need offer cause for real concern.

George Davis: In the over-all picture, economics must be considered, and from every angle. The author mentioned the effect of one and one-half pounds per gallon of fullers earth. I believe this would cost in the neighborhood of four or five cents a gallon of oil for the fullers earth, without the cost of equipment, labor, and down time.

In Figure 5, he shows some very excellent improvement in the normal properties of the oil. I might mention the fact that the inter-facial tension was increased to 25 dynes. The neutralization No. was reduced, I believe to 0.25. Those are excellent improvements, but it is a long way from being what would normally be considered new oil; I mention this because the inhibition picture is coming to the fore very rapidly. It has been found that the use of inhibitors is so much more effective when the oil is in the condition of a new oil or reclaimed as far as possible.

I believe some of the utility companies have gone to extremes in this respect, by reclaiming to a white oil standard, if you please, and then adding the inhibitors, but that is considerably different from the picture that Mr. Boal mentioned. For example, the neutralization No. was reduced from 0.25 against a new oil to 0.08, and in fact there is 300 per cent difference between the reclaimed oil and the new oil. I think we should all consider that.

As we know, the sludge and other soluble products of oxidation are very active catalysts in promoting further oxidation. The economy should be thoroughly investigated before deciding to reclaim or replace oil. Oils can be refined to a new condition, and this is very desirable if they are to be inhibited, but it costs too much except under conditions of extremely large use.

This is brought out by the practice of large power companies. Some of them replace oil; some of them have very elaborate reclaiming and additive programs; some are changing over to inhibitors.

In other words, we have a new tool to work with. Let us be sure that we work with it right before we go too far with it, because everybody seems to think that the inhibited oils offer promise. Let us not crucify them before we give them a full test.

Tentative List of Papers Scheduled for AISE Annual Convention

HOTEL SHERMAN, CHICAGO, ILLINOIS **OCTOBER 1, 2, 3, 4**

Control of Demand and Power Factor on Electric Arc Furnaces — by H. G. Heath

Multiple Generators for Processing Lines — by E. E. Vonada

The United Rendleman Rod Mill — by Norman Rendleman

Lubrication of Wire Rope — by C. H. Layton

Quality Control of Lubricants — by Carlyle R. Burton

Operative Results of One-way Fired Recuperative Soaking Pits at the Steubenville Plant of the Wheeling Steel Corp. — by James C. Stamm, Jr. and E. H. Cauger

Discussion of Crane Wheel Tread Contours — by John J. Stolz

Recent Developments Have Increased the Interrupting Capacity of Fusetron Fuses — by John C. Lebens

Organizing for Accurate Steel Mill Weighing — by K. A. Blom

Tons Per Square Foot of Hearth Area Production Characteristics — by H. F. Lesso

Cleaning and Use of Industrial Gases — by Jay J. Seaver

Characteristics and Operation of Coal and Ore Bridges — by E. L. Blankenbeker

Standardization in the Lubrication Department — by J. D. Lykins

Crane Runway Maintenance — by H. Russell Knust

Reconditioning Air Filter Oils — by George Findlay

Rectifier Application for Steel Mill Drives — by George B. Scheer

Roll Turning with Tracer Controlled Lathe — by Frank F. Zipf

Spray Lubrication of Open Gears — by Joseph A. Rigby

Operation of a 12-In. Continuous Bar Mill — by A. H. Griffiths

Latest Developments in Extrusion of Metals — by Erwin Loewy

A-C Power Distribution in Steel Mills — by D. L. Beeman

The Application of Bentone Lubricants to the Steel Industry — by D. H. Compondu

High Temperature-High Speed Heating for Steel Rounds — by A. F. Kritscher

The Axial Compressor for Blast Furnace Blowing — by W. O. Lowell

Combustion Gas Turbines and the Steel Industry— by W. B. Wilson

Flash Welding and High Speed Cold Reduction of Strip Steel for Tin Plate — by John Wargo and Ray C. Brunner

Rolling of Thin Strip — by M. D. Stone

Metallurgical Tips for the Maintenance Man — by Michael V. Herasimchuk

The Comparative Economics of Steel Melting in the Electric Arc Furnace and the Open Hearth — by H. W. McQuaid.

A New Method of Annealing Coils — by Lee Wilson

Blast Furnace Hearth Construction — by Owen Rice

Viscosity Control of Fuel Oil for Open Hearths — by Harvey Krouse

Modern A-c and D-c Crane Control for Steel Plants — by W. R. Wickerham and G. E. Mathias

Heat Relief in Hot Industries — by B. R. Small

AISE Standardization

Instrumentation and Control for Mixed Fuels

AND OXYGEN IN OPEN HEARTH FURNACES

By MARTIN J. CONWAY
Consulting Engineer
Gap, Pa.
and
EDWARD H. CAUGER
Chief Combustion Engineer
Wheeling Steel Corp.
Steubenville, Ohio

. . . . paper presented at Conference on Instrumentation for the Iron and Steel Industry, Pittsburgh, Pa., March 28, 1951 . . . .

▲ THE installation of controls and instrumentation on open hearth furnaces, in common with other furnace installations, is primarily to provide the operator with means to duplicate functional operation and obtain improved fuel consumption and increased furnace production. Most modern controls will remove the variations due to human error, if properly applied.

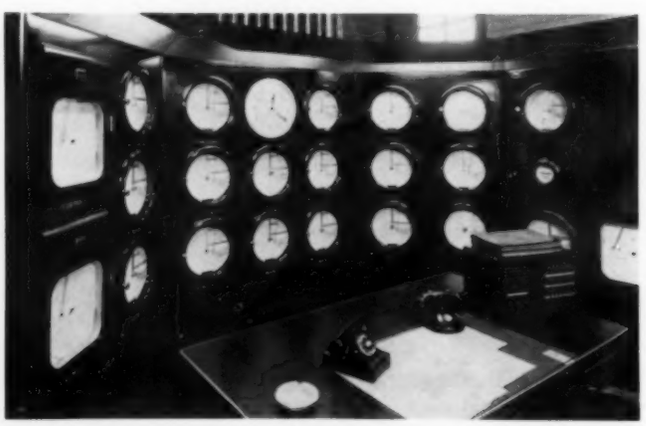
Instrumentation and control should be chosen with a view of minimum maintenance, ease of adjustment and simplicity of wearing parts rather than first cost. Fortunately, the source of supply is broad and reliable.

Before launching into a description of the instrumentation and control equipment installed on the open hearth furnaces at the Steubenville Works of the Wheeling Steel Corp., it may be well to mention that the types of fuel used are; coke plant tar, Bunker "C" fuel oil and coke oven gas. Naturally, tar and oil are not used simultaneously on any given furnace, but all furnaces can be switched from one liquid fuel to another as conditions demand. Present practice is to use the coke oven gas chiefly during the melt down period only, while tar is the preferred liquid fuel because of its high luminosity, radiating heat to the molten steel bath through the slag blanket better than oil. Coke oven gas being non-luminous, must release its heat by conduction and convection. In addition to the coke oven gas and liquid fuels, 95 per cent purity oxygen is used for both combustion and decarbonization.

The open hearth furnaces were designed and built originally to produce 60-ton heats and had ample regenerative chamber capacity to preheat sufficient air for burning the fuel to melt this tonnage. These same furnaces now produce heats of 170 tons, but sufficient preheated air is not available to melt this tonnage in reasonable time and with comparable fuel consumption. Therefore, combustion oxygen is introduced when burning more than 375 gallons of fuel oil equivalent per hour.

Oxygen is introduced into the molten metal bath

Figure 1 — Complete knowledge of all that is going on is given on the gas dispatcher's panel.



during the refining period of the heat, both for carbon reduction acceleration and for temperature requirements. The application is conventional and consists of inserting a ¾-in. lance into the bath through the wicket hole of the furnace door. A standard globe valve is used to control the volume of oxygen feeding the lance from a 110 psig oxygen line and a pressure gage indicates the pressure on the lance line. As a protection to the operator of the lance, a quick closing safety valve is installed on the outlet side of the globe valve, which in turn is held open by the helper regulating the oxygen to the lance.

A recording meter measuring all of the oxygen used for decarbonization on the 11 furnaces is installed on a

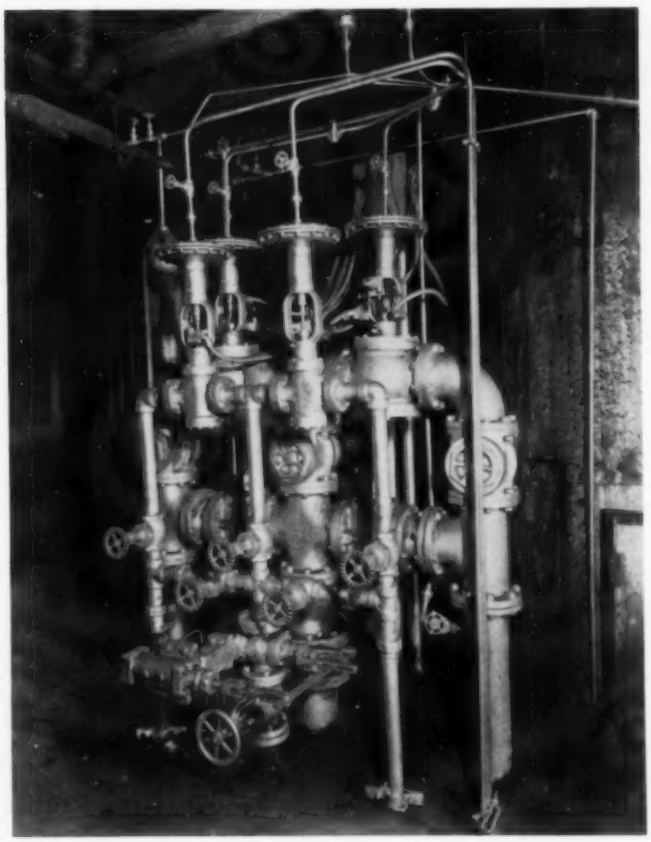


Figure 2 — Coke oven gas and oxygen manifold.

master panel in the gas dispatcher's office. This master panel is shown in Figure 1, and, together with the decarbonization oxygen meter, contains recording and indicating meters for the following services: total combustion oxygen; total coke oven gas available for distribution from the coke plant to the steel plant and other services; coke oven gas consumption in the boiler plants, strip mill and individual open hearth furnaces together with the coke oven gas consumption through the distribution line to the corporation's manufacturing plants located some 15 miles down-river from the Steubenville works. These are all indicating recorders, telemetered from integrating recorders.

The oxygen used in these operations is provided by an oxygen generating plant located adjacent to the open hearth shop and is delivered to the furnaces through

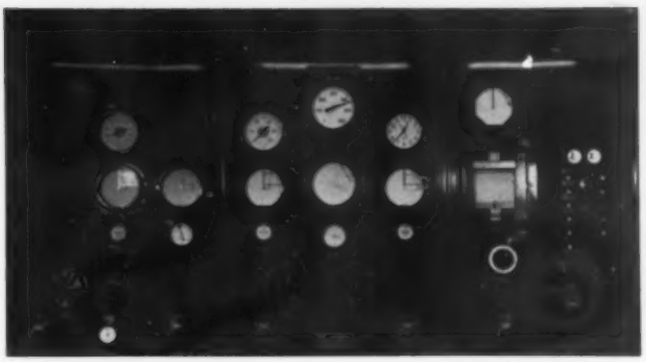


Figure 3 — Illustration shows outside of panel house.

the 110 psig line mentioned previously for decarbonization and refining, and through a 45 psig line for combustion. Furnace fuel and combustion controls are shown in Figures 2, 3, 4, and 5.

Tar temperature is maintained by a controller which regulates the steam to a tubular heat exchanger. This controller has a valve actor, whose purpose is to enable the instrument to accurately position the control valve with small changes in air pressure from the instrument itself, thereby overcoming any valve friction which may exist. The control valve is a double seated V-port valve comprising top and bottom guided construction.

FUEL OIL TEMPERATURE AND VISCOSITY CONTROL

Oil temperature can be controlled in a similar manner to the tar temperature and in addition a viscosity control is also used. The charts are recorded for flow control through this instrument, temperature and viscosity. The viscosity chart shows percentage of minimum viscosity, which is approximately 175 USS for present practice. There is a swing due to the lag between the viscosity controller and the valve controlling the steam input to the heater, which are some distance apart. The viscosity control installation is shown on Figure 6. The continuous viscosimeter is a simple adaptation of the well-known variable-area flow rate meter in which the flow rate is measured by causing fluid to flow vertically upward in a tapered tube as the flow rate increases, and drops as the flow rate decreases. The floats can be either viscosity sensitive or viscosity immune. By installing two floats in the tapered tube, one above the other, the lower float being viscosity immune and responding only to flow, and the upper float being viscosity sensitive, responding to both flow rate and viscosity change, a gap between the two floats is created, which in size is related to the viscosity.

The viscosimeter is installed in a by-pass of the main oil delivery line, and, a regular flow, enough to lift the lower float to a reference line, is put through the viscosimeter. Through the use of impedance coils located at the top and bottom of the unit, the rate of flow and the viscosity are transmitted to the recorder controller, from which is transmitted the air pressure to a diaphragm valve in the steam line to the oil heater, thereby making the required adjustments.

Figure 4 — This is inside of panel house illustrated in Figure 3.

The main steam supply line for liquid fuel atomization carries 250 psig superheated steam having a total temperature of 600 F. Normally, the atomizers used have been fabricated in the corporation's service shops and are the conventional "T" type, but after several months of experimentation, it has been decided to standardize on a commercial type of atomizer both for the reasons of uniformity and improved atomization.

Figure 7 shows the standard open hearth furnace burner used in these operations, which does not vary in design and is independent of the attached liquid fuel atomizers. It will be noted that the oxygen nozzle is in the lower position, it having been determined that the high temperature developed by the accelerated combustion of the atomized fuel due to the introduction of combustion oxygen, should be confined as close to the hearth and as far from the roof as possible. Several commercial type burners have been used experimentally with varying degrees of success but as their design does not allow for adjustment, it has been the practice to fabricate this part of the equipment in the corporation's service departments, and probably this practice will continue while searching for the best liquid fuel atomizing equipment to suit the furnace operation.

FURNACE PRESSURE CONTROL

The furnace pressure is measured at the crown of the furnace roof by pipe connections both inside and outside of the furnace and the differential is transmitted to the furnace pressure regulator mounted on the panel board. The value of the furnace pressure to be maintained is set on the indicating setting dial "A" (Figure 8) mounted on the front of the panel and the regulator controls the stack damper position by operating a double acting cylinder which is connected to the damper and counterweighted by means of sheaves and cables. It is important that the damper be as nearly counter-balanced as possible, thereby allowing the double acting cylinder to move the damper at the same speed in both directions.

Only one set of impulse lines is required to serve both the roof pressure recorder and the regulator.

FUEL CONTROL AND SUMMARIZATION

Figure 9 shows schematically the fuel control and summarization. The combustion controls are so arranged that the heat input or total Btu supplied to the furnace may be set by the operator. This is accomplished by adjusting handwheel "B" which acts through a mechanical computer or totallizer, which in turn controls the proportional amounts of liquid or gaseous fuel.

This operation is accomplished by converting the stroke of shaft "C" of the summarizer into a spring loading force by means of an adjustable cam, in turn causing the regulator to provide for a specific volume of liquid fuel.

By setting the amount of gas desired on handwheel "D," the stroke of shaft "E" of the summarizer is transformed into a spring loading pressure by means of an adjustable cam, thereby operating the regulator to provide for a comparable volume of gas in a similar manner as the liquid fuel is added.

Indication and recording of oil flow is accomplished by means of a conventional type area meter, however, measurement of fuel oil for the combustion control system is accomplished by means of a differential type meter with a pneumatic signal transmitting system, briefly described as follows: oil entering the differential meter body acts on a piston to maintain a constant differential across valve "F." In doing so, there is in effect a variable orifice across which a constant differential is maintained so that the position or opening of the orifice becomes an indication of flow.

Air pilot valve "G" is linked to the oil flow control valve so that it is similarly positioned. A pilot air flow is admitted to valve "G" and by means of a pressure regulator, a constant differential of air is maintained across this valve so that its position as well as the volume of air flowing through it, becomes a measure of oil flow. The pilot air flow is measured by an orifice and the up-stream pressure connection, which will vary approximately in accordance with the square of the air flow, is transmitted to the oil flow regulator to balance the spring loading pressure developed by the cam.

Coke oven gas flow is measured by a conventional orifice plate, and the impulse developed serves both an electric meter body, to remotely transmit the flow impulse to the recorder and totallizer, and the gas flow regulator. This differential balances the spring loading force developed by the stroke of shaft "E" of the summarizer. Coke oven gas pressure is also indicated by a conventional pressure gage.

OXYGEN AND AIR SUMMARIZATION

Figure 10 illustrates schematically the oxygen and air summarization. The output of the fuel computer or

summarizer is indicated by the stroke of shaft "H" of the summarizer which is connected to the total input shaft of the oxygen and air computer, signaling the adjustments for combustion air and/or combustion oxygen.

Shaft "I" of the summarizer with shaft "J" held stationary, would exactly match the stroke of shaft "H." Shaft "I" is connected to a cam, which in the same manner previously described, develops the spring loading force to provide for a specific volume of air to burn the amount of fuel reflected by the movement of shaft "H," by adjusting an air valve in the fan discharge. Air volume is measured by a conventional orifice plate and the impulse developed serves both an electric meter body, which transmits the flow impulse to a remote recorder, as well as balancing the spring loading force developed by the cam. The operator may replace a certain amount of atmospheric air delivered to the furnace with combustion oxygen delivered to the burner, and makes this adjustment by setting handwheel "K" to the desired oxygen volume. This in turn, through the computer or totallizer, deducts the air equivalent of the oxygen applied from the total delivered to the furnace. Oxygen volume is transformed by the stroke of shaft "J" of the computer, which calls for the required volume of oxygen in the manner described above, namely, by developing the spring loading force through a cam which in turn is balanced by the orifice measurement.

The differential developed by the orifice serves both the regulator and the electric meter body to transmit electrically flow impulse to the remote recorder. The regulator adjusts the oxygen flow through a plug type valve equipped with special packing and it may be well to add that the regulator impulse system is designed in such a manner that oxygen cannot come in contact with the oil serving as an hydraulic medium for the regulator.

Fuel-air ratio is adjusted by simultaneously setting the ratio sliders by means of handwheel "L" on the panel board.

ATOMIZING STEAM

The original system controlled the atomizing steam through a diaphragm valve actuated by a proportional control regulator which air loaded the steam flow valve. However, this method has been replaced by a pneumatic system of manually loading the diaphragm valve by a drift-proof regulator from the front of the panel board, to obtain the required steam flow. Steam flow is measured by an orifice and electric meter body for a remote totallizing recorder.

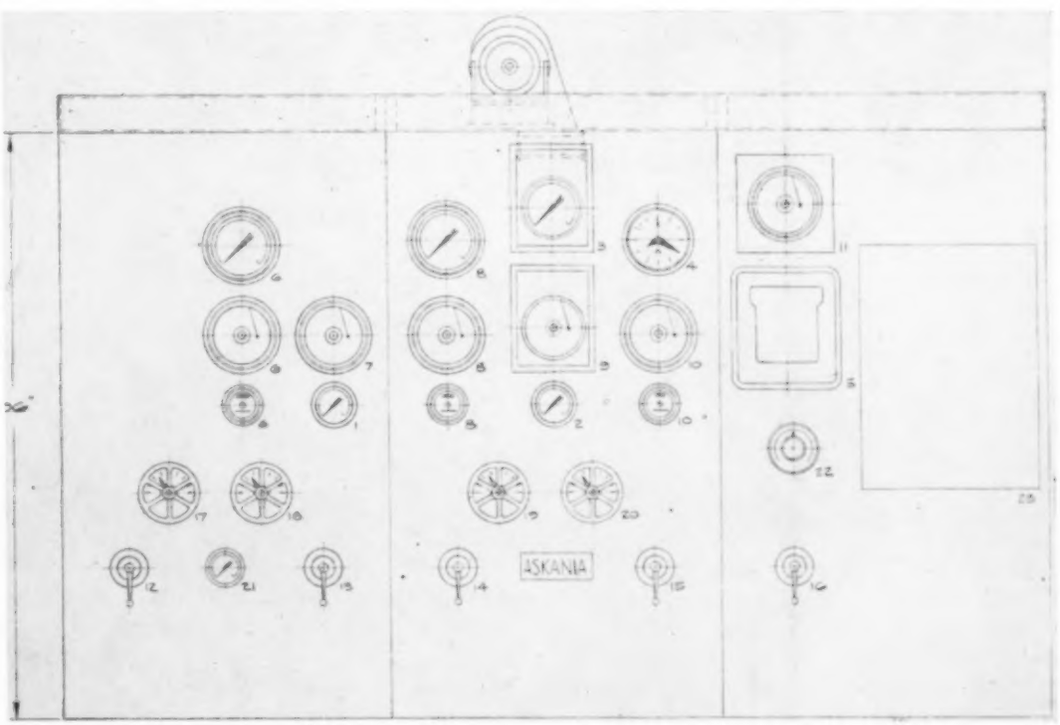
AUTOMATIC REVERSAL FROM TIME OR MAXIMUM TEMPERATURE

The furnace may be reversed from either maximum checker temperature or from a pre-set time interval. In either case the sequence of operation is the same.

The reversal valves for liquid fuel, steam, gas and oxygen are of the diaphragm type (Figure 11) and are operated through a solenoid three-way valve by which

Figure 5 — Legend diagram for panel house.

1. Oxygen pressure gage.
2. Coke oven pressure gage.
3. Oil flow indicator.
4. Clock.
5. Checker temperature recorder.
6. Combination oxygen flow recorder, totalizer, and indicator.
7. Air flow recorder.
8. Coke oven gas flow recorder, totalizer, and indicator.
9. Oil flow recorder.
10. Steam flow recorder and totalizer.
11. Furnace pressure recorder.
12. Oxygen—man/auto valve.
13. Air—man/auto valve.
14. CO gas—man/auto valve.
15. Total heat—man/auto valve.
16. Furnace pressure—man/auto valve.
17. Combination oxygen flow regulator.



18. Air flow regulator.
19. CO gas flow regulator.
20. Total heat input regulator.
21. Oil pump pressure.
22. Furnace pressure regulator.
23. Reversing cabinet.

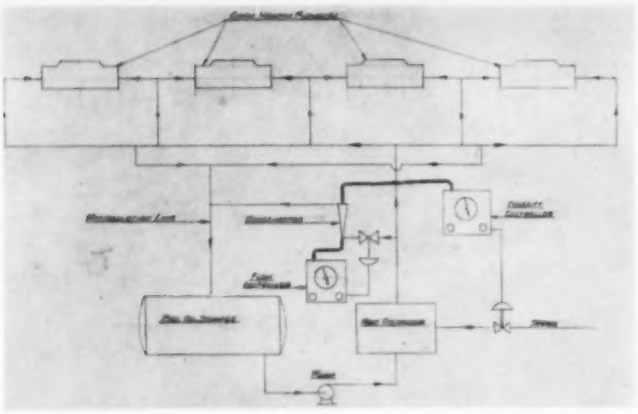


Figure 6 — The oil viscosity is controlled through the system shown in this schematic sketch.

air is admitted to the diaphragm motor by energizing the solenoid valve, or is exhausted from the diaphragm motor by de-energizing the solenoid valve.

Waste gas and combustion air are reversed by a double deck type damper operated by an electric motor.

The solenoid valves and damper motor starter are energized by the timer or checker temperature difference controller acting through suitable interlocks and necessary relays, to accomplish the sequence of reversal as follows:

Close north oil reversing valve "N_1."
Close north gas reversing valve "N_3."
Close north oxygen reversing valve "N_4."
Close north steam reversing valve "N_2 — delayed action.
Open south steam reversing valve "S_2."
Open south oxygen reversing valve "S_4."
Fuel, air, oxygen control valves and stack damper are locked in their existing position.
Waste gas and air valves are reversed.
Time interval is allowed to purge checkers before fuel is turned on.
Open south gas reversing valve "S_3."
Open south oil reversing valve "S_1."

Restore control to fuel, air, oxygen and stack damper to regulators.

CONTROL PERFORMANCE AND MAINTENANCE

In order to evaluate the controls and instrumentation heretofore described, it was deemed advisable to log a random heat and show a graphic representation of the flows and pressures as they occurred to contribute to a better understanding of the physical performance of the controls. The total results combine, not only the advantages of instrumentation and control, but also the use of combustion oxygen, refining oxygen and high hot metal heats.

By referring to the charts, it was noted that as coke oven gas was put on the furnace, the fuel oil was automatically reduced, whereas the Btu input remained constant.

The reduction of furnace air input corresponding to the combustion oxygen addition is not so readily seen, because simultaneously with the addition of combustion oxygen, the fuel input was increased and the fuel-air ratio control increased the air input. However, the furnace air, even after the increase of fuel input, did not exceed the quantity prior to the fuel increase, since the air-oxygen ratio control kept the air flow down in accordance with the amount of combustion oxygen being used.

The log also showed that the oxygen content of the waste gases was kept to the desired range of 1.5 to 2.5 per cent, except during the period that the heat was working violently and gases escaped from the furnace proper without being completely burned.

The steam input to the furnace was quite high. The proportional control for steam to oil is not in use since steam must be varied to control flame characteristics suitable for the period of the heat, and as the control cannot follow these conditions because the steam varies proportionately with the oil with this type of control. A ratio control whereby an excess or deficiency of steam could be set, similar to our fuel-air ratio control, would be desirable. Meanwhile, we set the air operated steam

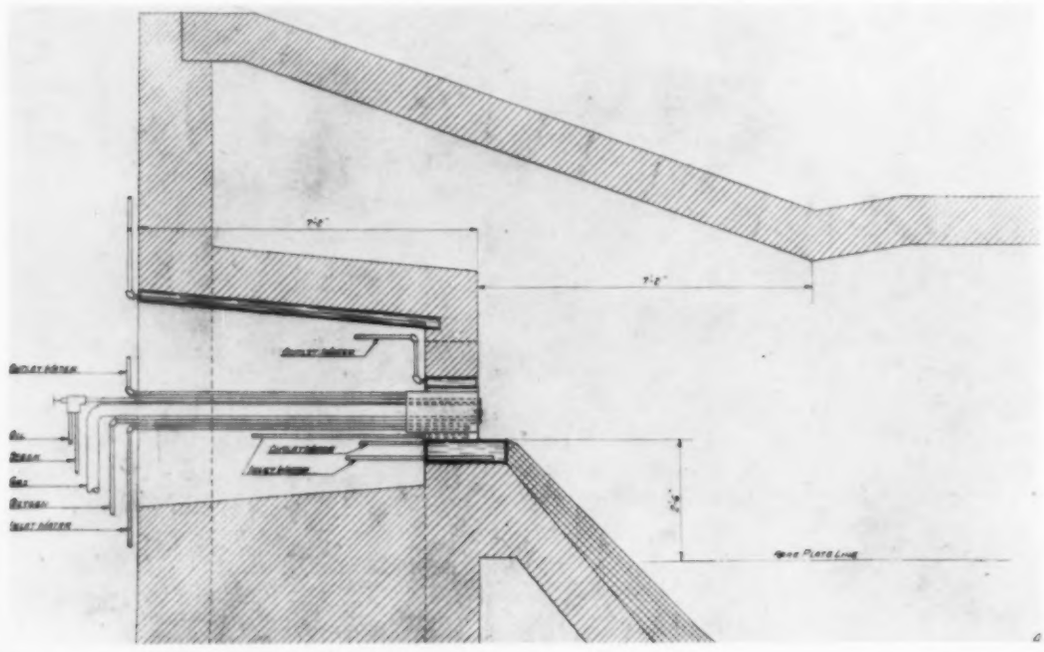


Figure 7 — Sketch shows design of open hearth burner.

valve remotely, at the panel, by means of the drift-proof regulator.

The furnace pressure chart shows that the automatic furnace pressure control held the furnace pressure to the desired regulation throughout the heat.

The checker temperature chart showed that after tapping the previous heat that the checkers became unbalanced while fettling and charging the subsequent heat.

This condition was readily remedied by setting the timers to allow the furnace to work from the hot end longer than the cold end, until both ends were brought into balance. As the checkers gained temperature, the furnace was reversed oftener. This was accomplished by resetting the timers for shorter reversals.

As already indicated, the automatic control system incorporates a means of reversal if the checkers should become too hot and endanger the brick work. This is not used since the impulse is derived from radiation units sighted to the top of the checker brick and erroneous temperatures can be registered due to wisps of flame or burning dust which are sometimes carried over with the waste gases.

It should be mentioned that the final installation of the open hearth furnace controls was made a little over a year ago. The fuel department personnel had to be trained in the functional use of the controls and their relationship to furnace operation in order to obtain the full benefit the controls were intended to produce, namely, increased production per furnace hour, lower fuel consumption per ton and increased refractory life.

Training of the furnace operators on the use of the controls and instrumentation had to proceed concurrently with the training of the fuel department personnel. This training is still in progress and there is still room for improvement. Naturally, changes and experiments are constantly being made which suggest further educational procedures. A field engineer from the fuel department covers the open hearth furnace activities and coordinates the distribution and production of the oxygen manufacturing facilities with the open hearth furnace requirements.

Field engineers from other sections are assigned to help in the open hearth on special tests or observations. Full time instrument repair service is maintained, which also functions to make the necessary waste gas analysis, furnace draft and infiltration tests and other work tending to improve furnace operation. The usual procedure is to run waste gas analysis after the first ten heats on a furnace campaign, and any adjustment necessary to compensate for air infiltration is set on the fuel-air ratio control. This does not preclude rectifying the cause for excessive infiltration. During the rebuild, all recorders are checked for calibration accuracy. Waste gas analysis are scheduled by the field engineer each week with a view of checking each furnace at least four times during a campaign, and, the results are reported to the assistant open hearth superintendent and the assistant chief combustion engineer.

Checker cleaning is scheduled by the field engineer each week and draft surveys are made and reported to show checker cleanliness. The field engineer, under the direction of the assistant chief combustion engineer, follows up all new installations, experiments and tests. The instrument repair foreman assigns personnel to the

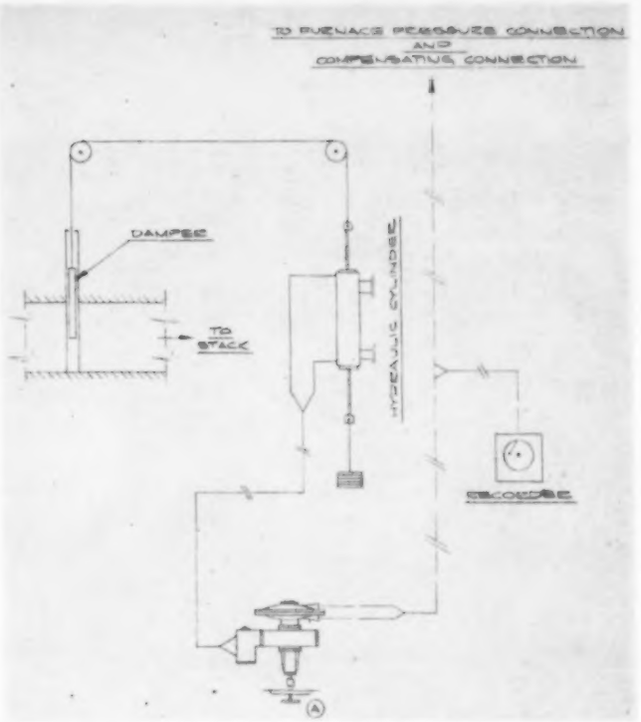


Figure 8 — Drawing shows schematic of furnace pressure control.

open hearth for around the clock coverage together with additional help as conditions warrant.

Figure 12 shows the responsibility area of the fuel department personnel with reference to the installation and use of instruments and controls together with maintenance.

Contributing to the training program for the full utilization of the instruments and controls are a series of "Combustion Advice" letters issued by the fuel engineering department to the furnace operating personnel. These letters explain to the operators the proper use of the control equipment, interpret the indicator and recorder readings and advise methods of securing the desired furnace results.

RESULTS

The installation of furnace instrumentation and controls and the application of combustion oxygen took place concurrently at the Steubenville works open hearth furnaces and the combined effect has resulted in a decided increase in production, a reduction in fuel consumption and an increase in checker life. General refractory life in the furnace proper, i.e. roof, frontwall, etc, has not been adversely affected. The use of combustion oxygen together with its control has had the beneficial effect of completing combustion in the furnace proper, thereby decreasing the erosion on endwalls, sidewalls and slag pocket walls, and fusion of checker brick.

Checker brick are still in good condition at the end of 1500 heats, whereas formerly a large proportion of the checker brick were replaced after 300 heats.

Table I shows a comparison of fuel utilization during periods in which the amount of hot metal charged was

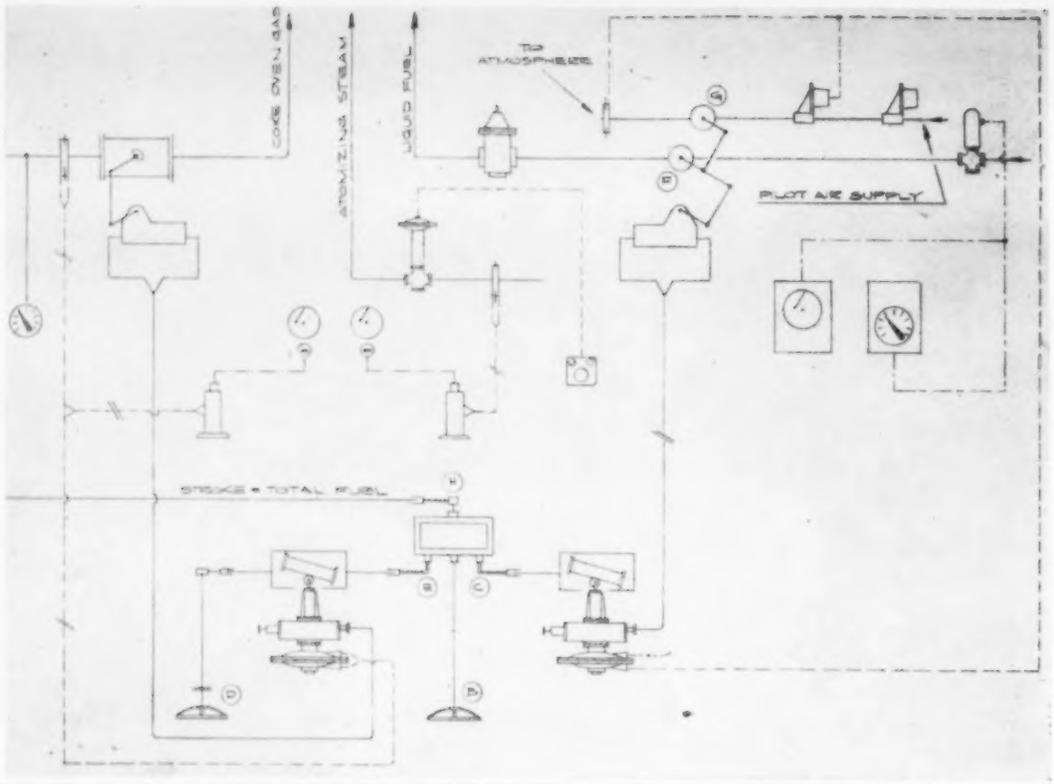


Figure 9 — Drawing shows schematic for fuel control and summarizer.

comparable. Some tar was used in the period for 1950, although it is not noted in the tabulation. No coke oven gas was used in 1947, and the reduction in fuel consumption for 1950 was 13.65 per cent under the 1947 figures and 15.08 per cent under the 1949 figures.

Except for the first few months of 1950 when operations were slow due to the coal strike, and, in November and December, 1950, when snow and flood conditions curtailed operations, the production increased and fuel decreased steadily, as can be noted by Figure 13.

The average production per furnace hour, charge to tap, in 1949 was 14.3 tons, while the average for 1950 was 15.6 tons, with a maximum of 16.9 tons per furnace hour being reached in October. The production rate in January, 1951, was 17.06 tons per furnace hour for a total shop production of 121,475 tons. The record monthly tonnage in 1950 was 117,646 tons as compared to the previous record of 102,452 tons in March, 1949.

Fuel consumption has declined steadily to a low of 3,289,653 Btu per ton recently established.

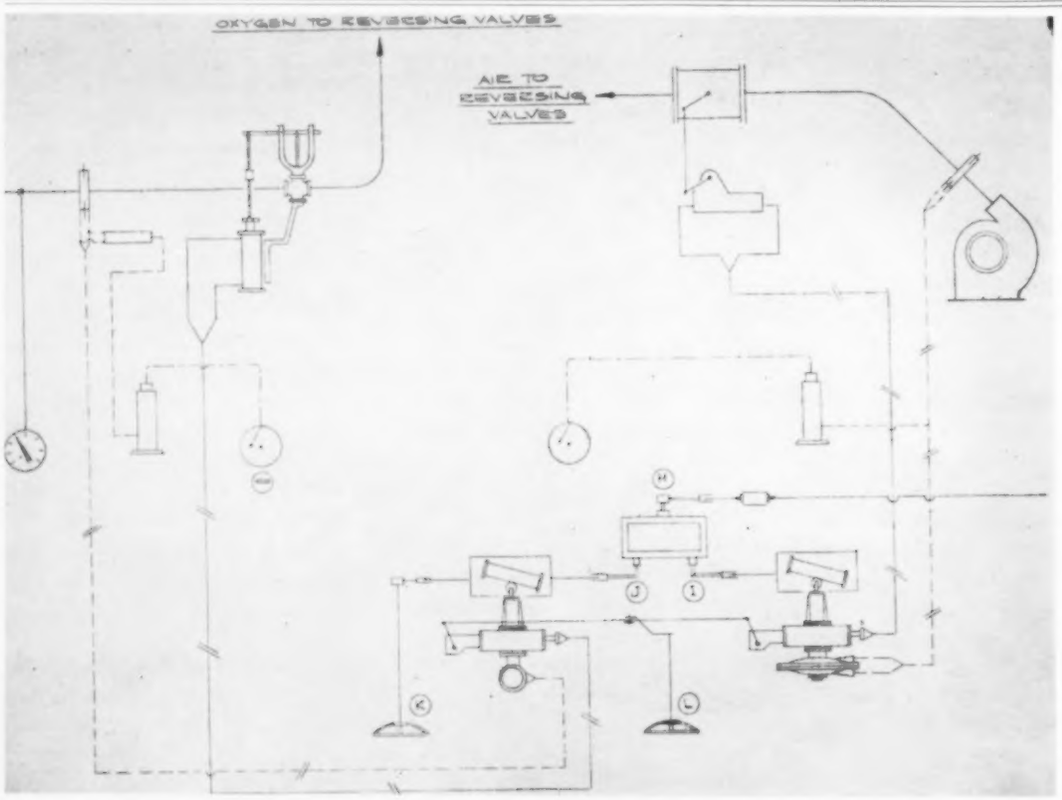


Figure 10 — Drawing shows oxygen air control and summarizer.

TABLE I

COMPARISON OF FUEL RATES DURING PERIODS OF SIMILAR HOT METAL PER CENT CHARGE

Month	Tons	Gal oil	Cu ft gas x 10^3	Gals tar	Btu/ton	Per cent CO gas
1947						
July	72,454	1,473,367	.....	512,547	3,936,000	.....
Aug	92,120	1,491,870	.....	911,159	3,783,000	.....
Sept	87,767	2,372,696	.....	.....	3,827,000	.....
Oct	98,083	2,656,283	.....	.....	3,849,000	.....
Nov	86,828	2,385,866	.....	.....	3,903,000	.....
Dec	93,073	2,690,731	.....	17,637	4,136,000	.....
Total	530,325					
Avg					3,905,000	
1949						
Jan	99,393	2,134,000	203,500	.....	4,074,000	24.6
Feb	90,698	1,986,488	169,700	.....	4,034,000	22.7
Mar	102,453	2,288,594	181,100	.....	4,049,000	21.3
April	100,005	2,192,832	168,900	.....	3,941,000	20.9
May	100,727	2,052,224	183,400	.....	3,772,000	23.6
June	71,418	1,799,711	55,468	.....	3,957,000	19.6
Total	564,694					
Avg					3,971,000	21.0
1950						
July	106,984	.....	.....	.....	3,334,000	8.6
Aug	114,353	.....	.....	.....	3,473,000	7.9
Sept	110,204	.....	.....	.....	3,372,000	7.8
Oct	117,646	.....	.....	.....	3,332,000	8.7
Nov	110,480	.....	.....	.....	3,290,000	6.9
Dec	113,312	.....	.....	.....	3,427,000	4.8
Total	672,979					
Avg					3,372,000	7.2

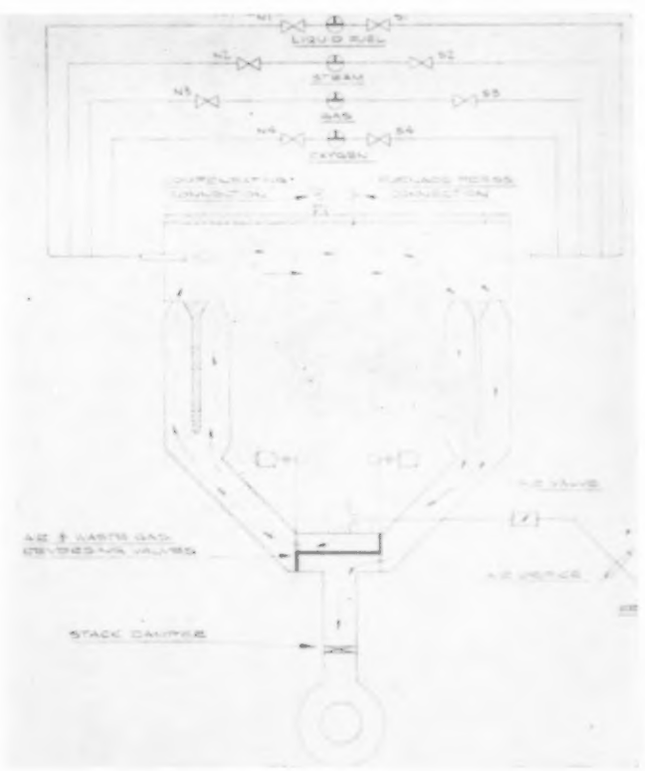
Oxygen consumption during the record month of October, 1950, was at the rate of 95 cu ft per ton for decarbonization and 492 cu ft per ton for combustion, and as can be readily deduced from the foregoing, the installation of instrumentation and controls has been justified. It should be readily possible to increase production by 30 per cent and reduce fuel consumption by 20 per cent as is shown by comparing our January figures with the previous base of 90,000 tons per month. Increasing the hot metal charge from 45 to 60 per cent accounts for 10 per cent of the increase, while the use of combustion and refining oxygen accounts for 15 per cent of the benefits derived from the program instituted to increase production. We estimate that instrumentation and controls have contributed 5 per cent to the additional tonnage and facilitated handling of the combustion oxygen.

CONCLUSIONS

Some analysis of the draw-backs which were incurred with the original instaflation and the possibilities of improving and adding to the control system should be mentioned in concluding this paper.

We have indicated that the original atomizing steam-oil ratio control was a proportional straight line control which was not suitable for developing flame characteristics desirable at certain stages of the heat, and that manual air loading of the atomizing steam valve was resorted to. An automatic steam-oil ratio control similar to the fuel-air ratio control would be desirable, in order that an excess or deficiency setting of the steam could be used at any oil flow to develop desired flame conditions.

Figure 11 — Furnace reversal may be based on either checker temperature or from a preset time interval.



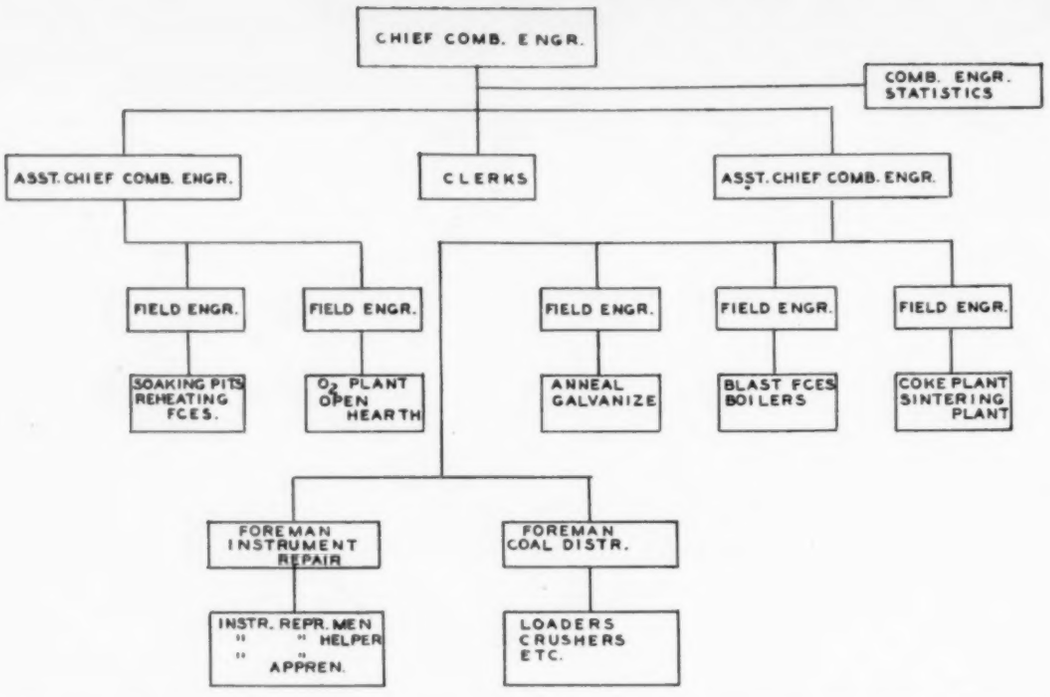


Figure 12 — Organization diagram for fuel department.

The automatic reversal based on radiation impulse from the top of the checkers led to excessive reversals due to erroneous temperature readings caused by atmospheric conditions in the checkers. A reversal system based on checker temperature difference, impulsed by thermocouples in the checker brickwork, is going to receive investigation in the near future.

This will be interlocked with the automatic time reversal so that the furnace will reverse at a given checker temperature difference or at a preset time. We are not sure that this type of control will perform for our purpose, efficiently.

A desirable addition may be that of controlling the temperature of the metered air to the furnace or at least compensating for the change in temperature. Temperature of air changes, of from zero to 100 F during the various seasons of the year, can cause a change of substantially 10 per cent in the weight of oxygen delivered to the furnace.

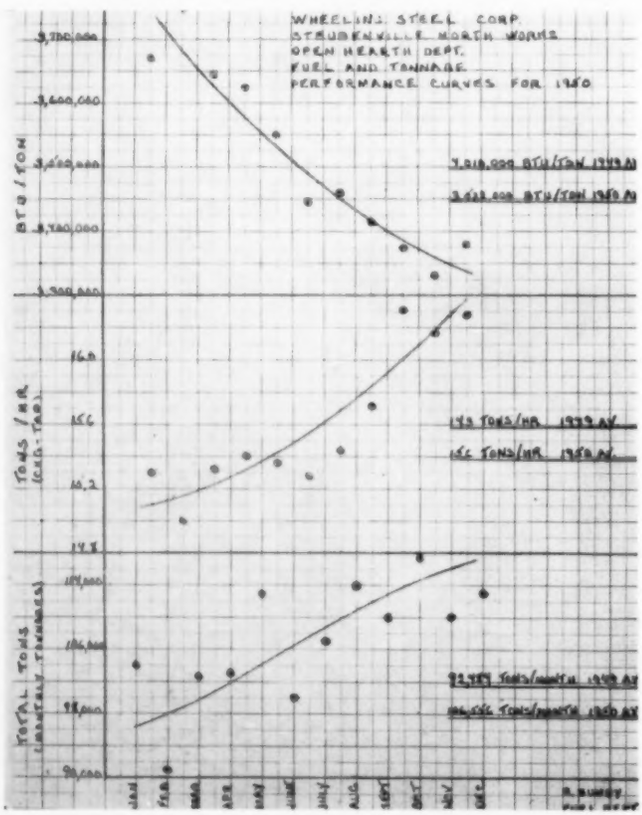
One method of compensating for this difference may be the automatic adjustment of air input from continuous waste gas analysis. Roof temperature control has been widely applied in the industry. However, the lag between the shutting off or throttling of the fuel and the effect on furnace performance is such as to question the value of this control, but the use of a roof temperature recorder as a warning device is desirable.

Automatic control of bath temperatures would make an interesting study, especially so, when all of the variables are considered. Meanwhile, we must be satisfied with a means of measuring the bath temperature, which if properly interpreted, contributes to steel quality, ladle life, yield, mold and stool life, etc.

The type of instrument used in determining bath metal temperature is largely an individual shop problem, depending upon shop layout, type of personnel available, and grades of steel produced. In our case, we have already experimented with the open end blow pipe radiation unit and expect to run similar tests with a thermocouple type of bath temperature unit.

The control system herein described was carefully planned and thoroughly engineered before installation as a unit, and the results obtained, almost from the start of operations, justified the procedure. Too often, in our anxiety to obtain certain results by steps, instrumentation and control is installed in a fragmentary manner with the result that the control system as a unit fails to perform in the manner intended.

Figure 13 — Fuel requirements for 1950 were reduced from about 3,700,000 Btu at the beginning of the year to 3,350,000 Btu at the end of the year.



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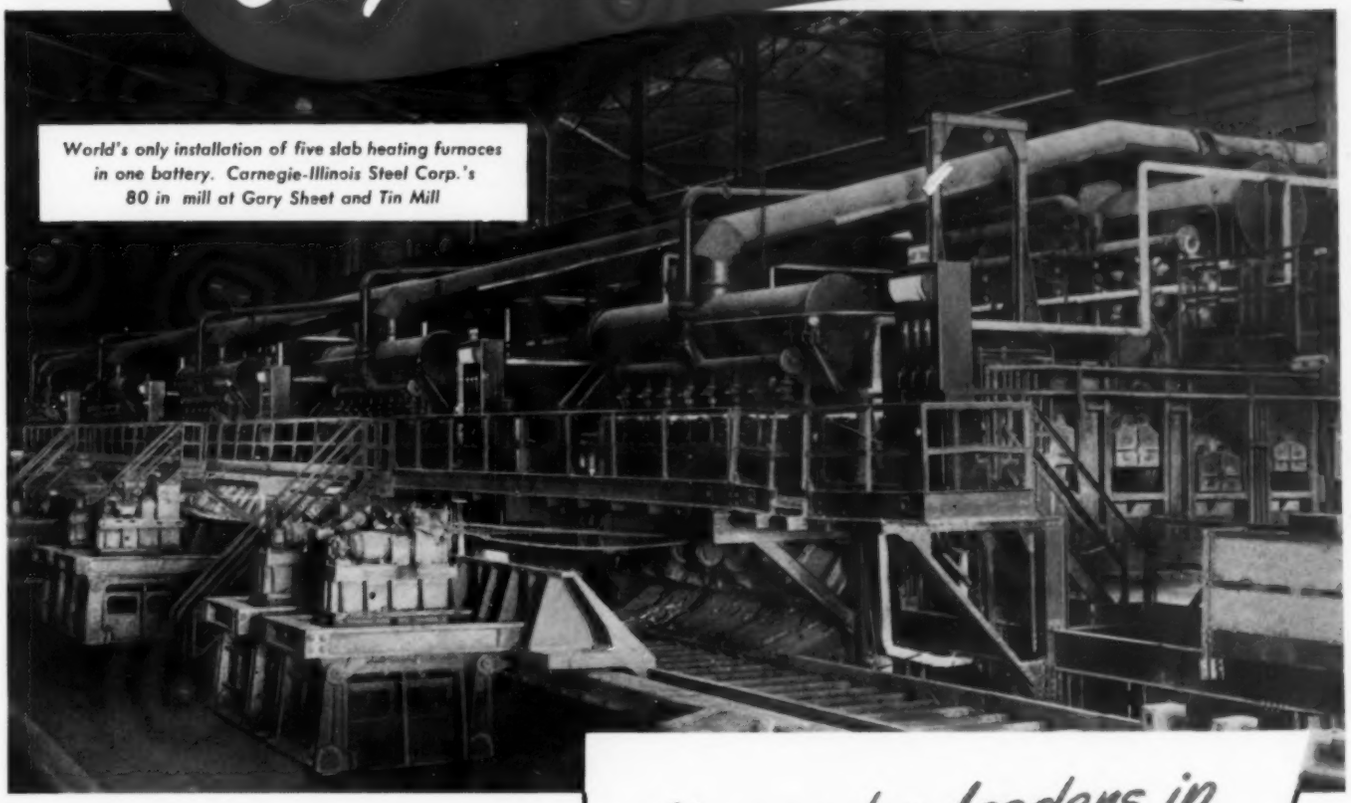

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Because PERFORMANCE is so important, leading steel makers throughout the world use RUST patented, zone-controlled, double or triple-fired, recuperative, continuous furnaces. They are individually designed to reheat slabs, blooms, billets, bars and other shapes.

Nearly 200 Rust installations, ranging in capacity from 20 to 115 net tons per hour, represent more than one-third of the heating capacity (excluding soaking pits) of America's iron and steel industry. Present conditions call for utmost efficiency and economy in production. Time to consult Rust.

RUST

RUST FURNACE CO.

PIONEERS IN FURNACE DESIGN

PITTSBURGH, PENNSYLVANIA

Phone ATlantic 1-5870

F-1

75 Years OF LUBRICATION SERVICE

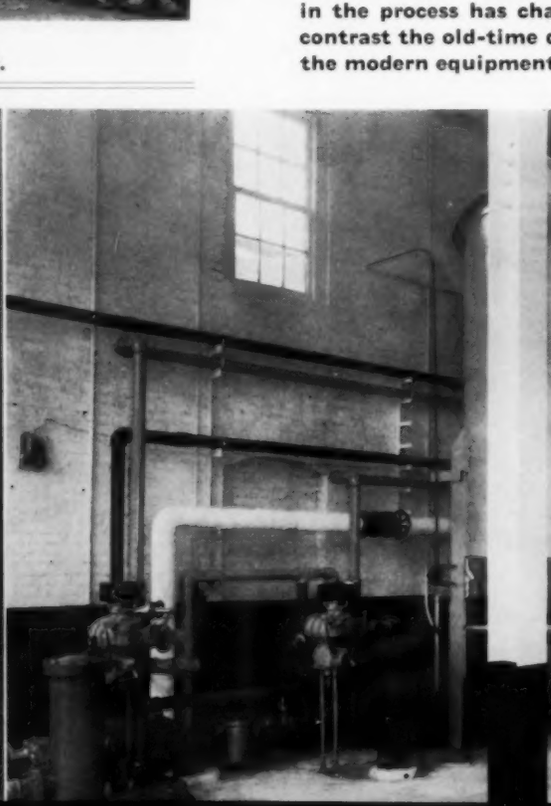
Brooks' 75th birthday cake was cut by 84-year-old Mrs. Alice Wallace Ward, widow of Alexander M. Ward, who was Brooks president from 1896 to 1941, and mother of Alfred W. Ward, who is now chairman of the board.

▲ IN 1876, as the United States of America celebrated its centennial, the young nation's industrial sinews were beginning to form the pattern that was to develop into today's marvelous production machine. The new Edgar Thomson plant had just begun production, and the steel industry was in the midst of revolutionary new developments.

Amid this bustle of industrial activity 75 years ago, Alfred Whitaker, of Cleveland, Ohio, formed the Brooks Oil Co. to refine and market kerosene, which was the principal source of illumination at that time. Shortly thereafter, the company began compounding lubricants, including harvester oil, axle grease, harness oil, engine and cylinder oil, etc., most of which were sold to farmers. With the growth of the automobile, the company established the first filling stations with gasoline pumps in Cleveland.

Brooks employees, 1889.

The compounding of industrial lubricants has become a science, rather than an art, and the equipment used in the process has changed. The photographs below contrast the old-time direct-fired kettle with some of the modern equipment.



. . . . . the history and growth of companies such as Brooks Oil illustrates the opportunities available in this country for someone with initiative, ability and aggressiveness . . . . .

The Brooks organization is now headed by Fred H. McCurdy, president (left), and Alfred W. Ward, chairman of the board.

Meanwhile, lubricants continued to play an important role in Brooks' activities, and by 1932 the company was producing Leadolene lubricants capable of withstanding pressures up to 25,000 psi, about three times what the run-of-mine products of that day would take. At that time the company decided to get out of the gasoline business and concentrate on compounding industrial lubricants. Research was intensified to improve existing products and develop new ones. Over the years, as the size of industrial equipment increased, Brooks lubricants were developed to meet pressures as high as 50,000 psi. Klingfast appeared, as well as various high temperature lubricants and a roll oil, a domestic substitute for palm oil on cold strip mills.

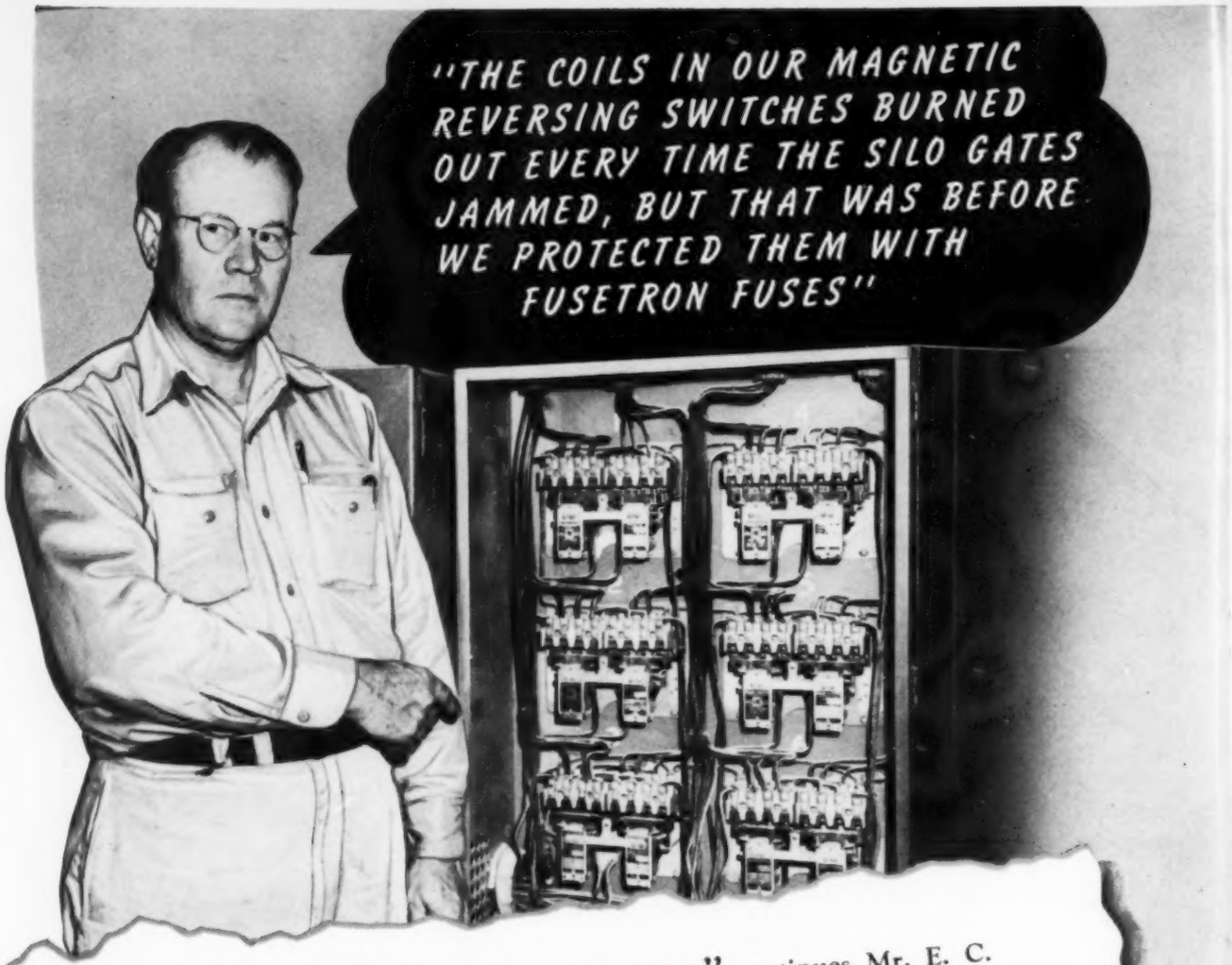
It is indeed fitting that Brooks was founded in the midst of feverish development in the steel industry, as it has grown up with that industry. Today, offices and warehouses are located primarily in the country's steel producing centers. The company renders service to 85 per cent of the iron and steel industry, and 95 per cent of the company's business is with that industry.

Brooks has built an enviable reputation by solving the difficult lubrication problems of the steel industry. Brooks products are used for circulating systems, hydraulic systems, open and enclosed gearing, worm gearing, all types of bearings, flexible couplings, and wire rope. Applications are to be found on mill reduction gears and pinion, mill tables, screwdowns, manipulators, shears, cranes, levelers, straighteners, roll lathes and grinders, machine tools, railroad equipment — in short, all types of plant equipment. Every application is carefully studied — no "cure-all" is offered.

Though not an industrial giant, Brooks Oil Co. is among the largest compounders of industrial lubricants. As is the case with many of our smaller industrial organizations, Brooks' success is based on the perfection of specialized products and the tradition of intimate, specialized service that is a part of their business philosophy — a philosophy that has carried the company through years of industrial activity and growth to its diamond anniversary.

Joseph A. Rigby, (left) vice-president of engineering and sales, and W. Morrison, senior vice-president, are also supervisors of the Brooks "team."

H. W. Winkler, also a vice-president, is in charge of research and laboratory control.


"THE COILS IN OUR MAGNETIC REVERSING SWITCHES BURNED OUT EVERY TIME THE SILO GATES JAMMED, BUT THAT WAS BEFORE WE PROTECTED THEM WITH FUSETRON FUSES"

"Sure! *you can quote me,"* continues Mr. E. C. Willy, Chief Electrician, H. J. Kaiser Co., Radum Plant, Pleasanton, Calif.

"In the past, we found magnetic reversing switches welded the main contacts when Silo Gates jammed. When reverse control operated, the armature could not properly engage, resulting in a burned out coil.

"The coils cost about $4.00 each, but most important was the substantial production loss each time the coil burned out.

"We now have 4/10 ampere Fusetron dual-element fuses installed to protect these coils. During the year 1950 we blew about 100 Fusetron fuses, but didn't lose any coils. This represents a saving of at least $400.00 in coils and kept me from being dragged out of bed at night, an occurrence that often happened before. Then, too, we can replace burned out Fusetron fuses much faster than we can replace coils, to say nothing of the valuable production time we save."

Facts about Fusetron *dual-element* Fuses

- The fuse link element opens on short-circuit — the thermal cutout element protects on overloads — the result, a fuse with tremendous time-lag and much less electrical resistance.
- They have the same degree of Underwriters' Laboratories approval for both motor-running and circuit protection as the most expensive devices made.
- Made to the same dimensions as ordinary fuses — fit all standard fuse holders.
- Obtainable in all sizes from 1/10 to 600 ampere, both 250 and 600 volt types. Also in plug types for 125 volt circuits.
- Their cost is surprisingly low.

FUSETRON

TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION

BUSS

"You too, can get 10 Point Protection by using Fusetron (DUAL-ELEMENT) Fuses"

1 * Protect against short-circuits.

2 Protect against needless blows caused by harmless overloads.

3 Protect against needless blows caused by excessive heating — lesser resistance results in much cooler operation.

4 Provide thermal protection — for panels and switches against damage from heating due to poor contact.

5 Protect motors against burnout from overloading.

6 Protect motors against burnout due to single phasing.

7 Give DOUBLE burnout protection to large motors — without extra cost.

8 Make protection of small motors simple and inexpensive.

9 Protect against waste of space and money — permit use of proper size switches and panels.

10 Protect coils, transformers and solenoids against burnout.

★ Fusetron Fuses have high interrupting capacity as shown by tests of Electrical Testing Laboratories of New York City in December 1947.

Don't Risk Losses!

One **destroyed** switch or panel . . .
One **needless** shutdown . . .
One **lost** motor . . .

May cost you far more than replacing every ordinary fuse with a Fusetron dual-element Fuse.

Mail the Coupon Now!

Bussmann Mfg. Co., University at Jefferson
St. Louis 7, Mo. (Division McGraw Electric Co.)

Please send me complete facts about FUSETRON dual-element Fuses.

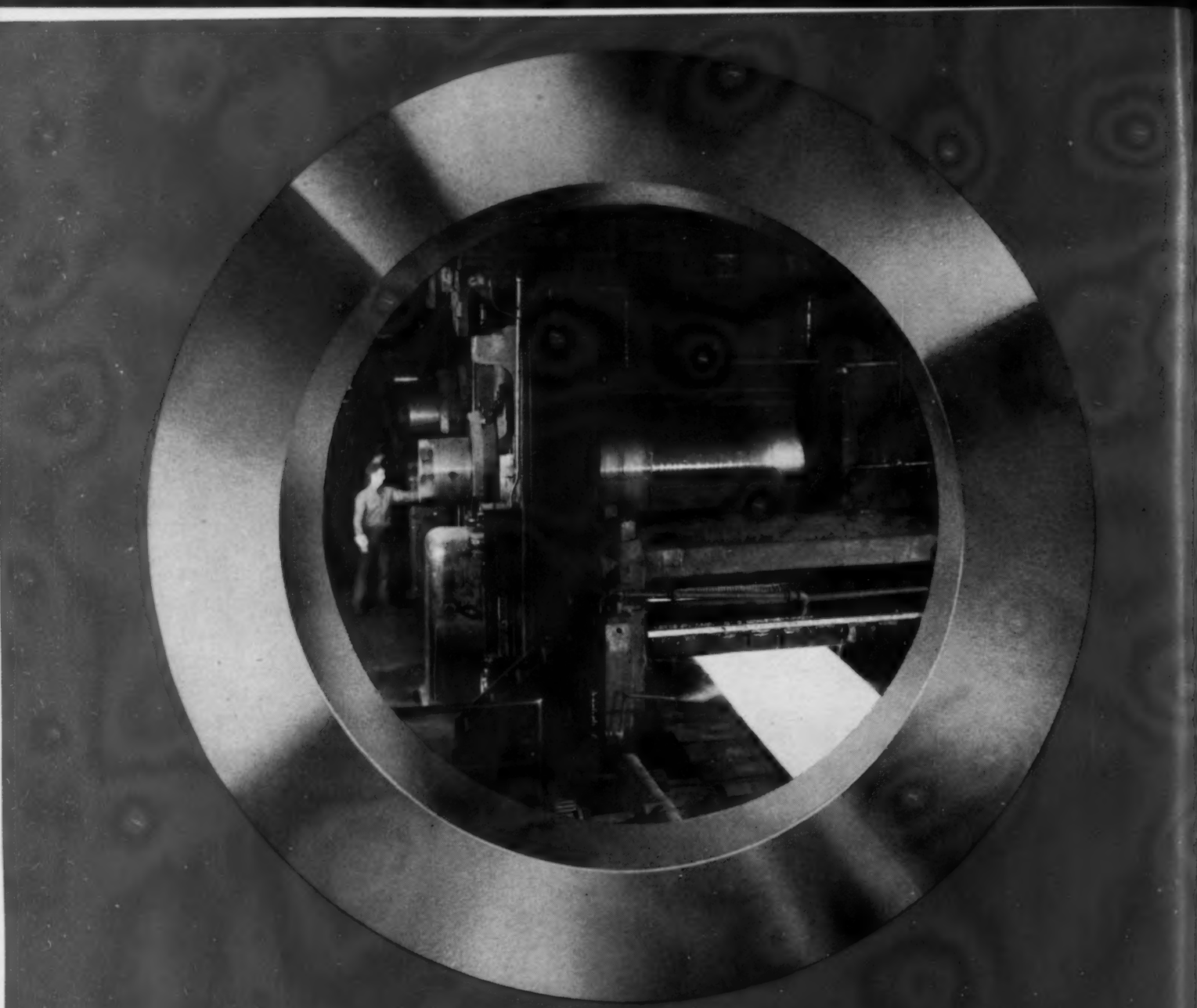
Name.....

Title.....

Company.....

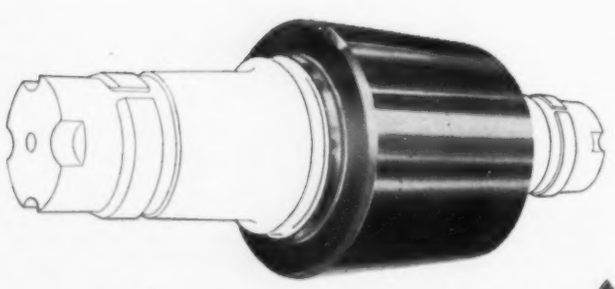
Address.....

City and Zone..... State 751



Custom-built to roll more tons . . .

Heppenstall Sleeves



Don't scrap worn rolls—re-sleeve them!

Heppenstall back-up roll sleeves roll record tonnages . . . last longer in high speed service because their design permits more effective forging and heat treating operations.

Made from Heppenstall's own steels, each sleeve is mandrel forged—worked thoroughly to produce maximum density and grain refinement. With careful heat treating, the working surface of every sleeve is tempered to meet exact hardness specifications. Heppenstall also makes forged arbors . . . has facilities to grind arbors and sleeves for perfect shrink fitting. Heppenstall Company, Pittsburgh 1, Pa. Sales offices in principal cities.

Heppenstall

—the most dependable name in forgings

Date-line Diary...

June 1

▲ NPA issued regulations on use of scarce metals for third quarter. Use of steel in consumer durables other than automobiles was cut 30 per cent from pre-Korean levels.

June 2

▲ RFC cut tin price from $1.39 to $1.36 a lb.

▲ Under OPS regulation, steel producers must absorb some of the recent 6¢ a lb increase in nickel price.

June 4

▲ According to the AISI, operating rate of steel industry for the week beginning June 4 is scheduled at 103.2 per cent of capacity. This is equivalent to 2,063,000 tons of ingots and castings compared with 2,053,000 tons one week ago.

▲ Iron ore shipments down the Great Lakes in May were 33 per cent above the same month in 1950.

June 5

▲ Oil companies raised heavy fuel oil prices along eastern seaboard from 17 to 31¢ a barrel.

▲ The aluminum industry produced 135,402,337 lb compared with 140,044,429 in March. Shipments of aluminum sheet and plate totaled 93,963,648 lb slightly under March.

June 6

▲ Barium Steel Corp. blew in its Chester, Pa., blast furnace.

▲ Census Bureau reported that unemployment in May dropped to 1,609,000 or the lowest since August 1945.

▲ American Railway Car Institute reports that orders placed for new freight cars during May totaled 4919; new cars built totaled 9774, leaving a backlog on June 1 of 150,628.

▲ Westinghouse Electric Corp. and IUE-CIO reached an agreement for a one-year extension of their contract. Agreement includes a 9¢ per hour wage increase.

June 7

▲ United States Steel blew in its enlarged No. 5 blast furnace at Youngstown, Ohio.

▲ R. G. LeTourneau, a manufacturer of dirt moving equipment, is building a steel mill next to its plant at Longview, Texas.

▲ The Justice Department dismissed its eleven-year-old anti-trust suit against the oil industry.

▲ Alcoa announced that its stock will be listed on the New York stock exchange effective June 11, 1951.

June 8

▲ Commerce Department reported that manufacturers' sales climbed sharply in April with a total of $22,300,000,000, down $1,100,000,000 for March. Inventories increased in April to $37,700,000,000.

June 9

▲ Crucible Steel Co. closed one of its nine open hearth furnaces at Midland because of a shortage of scrap.

▲ Judson Steel Corp., Emeryville, Calif., was granted a $4,600,000 certificate of necessity for an expansion of its rolling mill facilities.

▲ Colorado Fuel and Iron filed application for certificate of necessity for a $109,600,000 strip and sheet mill to be built in Tonawanda, N. Y.

June 11

▲ High coal stocks have resulted in lay-offs in many coal mines.

▲ According to the AISI, the operating rate of the steel industry for the week beginning June 11, 1951, is 103.2 per cent of capacity. This is equivalent to 2,063,000 tons of steel compared with 2,063,000 tons one week ago.

June 12

▲ Agriculture Department estimated 1951 wheat crop at 1,054,000,000 bu, or 27,000,000 more than last year.

▲ House Ways and Means Committee approved a proposed 20 per cent withholding tax on dividends, royalties and most types of interest.

▲ Pittsburgh Steel Co. proposed a 50 per cent increase in the authorized number of common shares to be used to acquire the assets of Thomas Steel Co.

▲ Bethlehem Steel Co. contracted with the M. A. Hanna Co. for delivery of 30,000,000 tons of Labrador-Quebec iron ore over a 25 year period.

▲ Commerce Secretary Sawyer credited rapid amortization for the present expansion in the steel industry.

June 13

▲ Export-Import Bank approved a $5,000,000,000 credit which will be used in expanding the Altos Hornos de Mexico mill located at Monclova, Mexico. Expansion includes a blast furnace, improvements to and additional open hearth capacity.

▲ Ohio Seamless Tube Co. is starting a $2,500,000 expansion program which will include a 48-ft rotary furnace, a billet piercer and other equipment for the seamless mill.

June 14

▲ Canadian pig iron went up $3.00 a ton.

▲ RFC cut tin price 6¢ to $1.23 a lb in New York.

▲ The F. W. Dodge Corp. announces that construction contracts in the 37 states east of the Rockies during May totaled $2,572,961,000 or 91 per cent more in the same month one year ago.

▲ AISI reports that estimated employment during April set a new record of 665,700. Wage earners received an average of $1.926 an hour in April and worked an average of 40.5 hours a week. Total payroll was $234,769,000.

June 15

▲ RFC cut tin price 5¢ to $1.18 a lb.

June 16

▲ RFC cut tin price 7¢ to $1.11 a lb.

June 18

▲ Based on reports from companies having 93 per cent of steel capacity of the industry, the AISI announced that operating rate for the week beginning June 18 is scheduled at 103.2 per cent of capacity. This is equivalent to 2,063,000 tons compared with 2,063,000 tons one week ago.

▲ RFC cut tin 5¢ to $1.06 a lb.

June 19

▲ FTC announced that it will issue an order shortly in which steel companies will be prohibited from banding together to carry out any planned course of action.

June 20

▲ According to a government survey, plant expansion expenditures for the second quarter of this year total $6,420,000,000.

▲ Jones & Laughlin Steel Corp. awarded Rust Engineering Co. a contract to build a water treatment plant at the Pittsburgh works with a capacity of 4000 gpm.

▲ Republic Steel Corp. bought the government steelmaking facilities at Canton, Ohio, from the RFC for $1,534,391.

▲ Jones & Laughlin Steel Corp. filed a suit for about $3,300,000 against the F. H. McGraw & Co. Jones & Laughlin charges that the $10,000,000 coal washing plant recently built is not working properly.

June 22

▲ Government cut rubber price 14¢ to 52¢ a lb.

▲ House approved an annual tax boost of $7,200,000,000 including individual income, corporate income, excess profits, capital gains and excise taxes.

▲ According to Ward's Automotive reports auto production in the United States this year will reach 5,497,000 units or 1,174,911 cars below last year's record.

June 23

▲ Republic Steel received its first cargo of iron ore from West Africa today. Ship docked at Baltimore.

▲ Allegheny Ludlum Steel Corp. was licensed by Armco to use patents covering processes for the production of special types of electrical sheets.

▲ Pacific States Steel Corp. is adding a third and fourth open hearth furnace which will have a capacity of 150 tons each.

June 24

▲ Lone Star Steel reported that construction commitments for its new integrated steel mill in east Texas had reached a total of $32,781,799. Estimated cost of mill is $75,425,201.

June 25

▲ Sharon Steel Corp. is planning to construct a $1,250,000 coal washing plant at its mine in Rachel, West Va.

▲ According to the AISI, the operating rate for the steel industry for the week beginning June 24 was scheduled at 102.8 per cent of capacity. This is equivalent to 2,055,000 tons compared with 2,063,000 tons one week ago. The AISI estimates that over 52,000,000 tons of steel will be made during the first half of 1951.

▲ Stocks broke sharply on the Russian proposal for Korean cease-fire talks.

▲ The AISC reported the May bookings for fabricated steel totaled 267,355 tons compared with 337,206 tons for April. Shipments in May totaled 233,087 tons compared with 234,707 tons in April, leaving a backlog for the next four months of 1,120,920 tons and a total backlog of 2,771,264 tons.

June 27

▲ Aetna-Standard Engineering Co. started a $3,000,000 expansion program at Ellwood City.

▲ NPA announced that the date for steel mills to use CMP has been set back until July 7.

▲ Automobile companies in general are cutting back assemblies to come within the quota set by the NPA.

June 28

▲ The Agriculture Dept. reported that farmers' incomes for the first half of 1951 were 20 per cent ahead of a year ago with a total figure of $13,200,000,000.

▲ House leaders are supporting a 30-day extension of present price wage and rent controls, but will not approve any price roll backs during that period.

▲ McLouth Steel Corp. has been awarded a certificate of necessity which will enable it to about double its capacity at Trenton, Michigan. Program includes coke ovens, a new blast furnace and three open hearths.

June 29

▲ Secretary of Treasury Snyder asked the Senate to increase the $7,200,000,000 tax bill, approved by the House, by at least $3,000,000,000.

▲ Allegheny Ludlum Steel Corp. increased prices of nickel bearing steels to reflect some of the additional cost caused by the raise in the price of nickel.

▲ Ford Motor Co. announced they will build an aircraft accessories plant at Ypsilanti, Mich.

▲ Government of Great Britain announced, as a part of the defense program, it will allocate iron, steel and some nonferrous metals.

June 30

▲ Congress passed and sent to the White House, stop-gap legislation to extend controls until the end of July.

▲ Bolivia is negotiating with the RFC and the State Department to get the United States to set a minimum price on tin.

▲ Wean Engineering is building a continuous strip cleaning line, pickling line, electrolytic tinning line, combination temper mill and shearing line for the Fairless Works. Pickling line will have the largest capacity of any in the world.

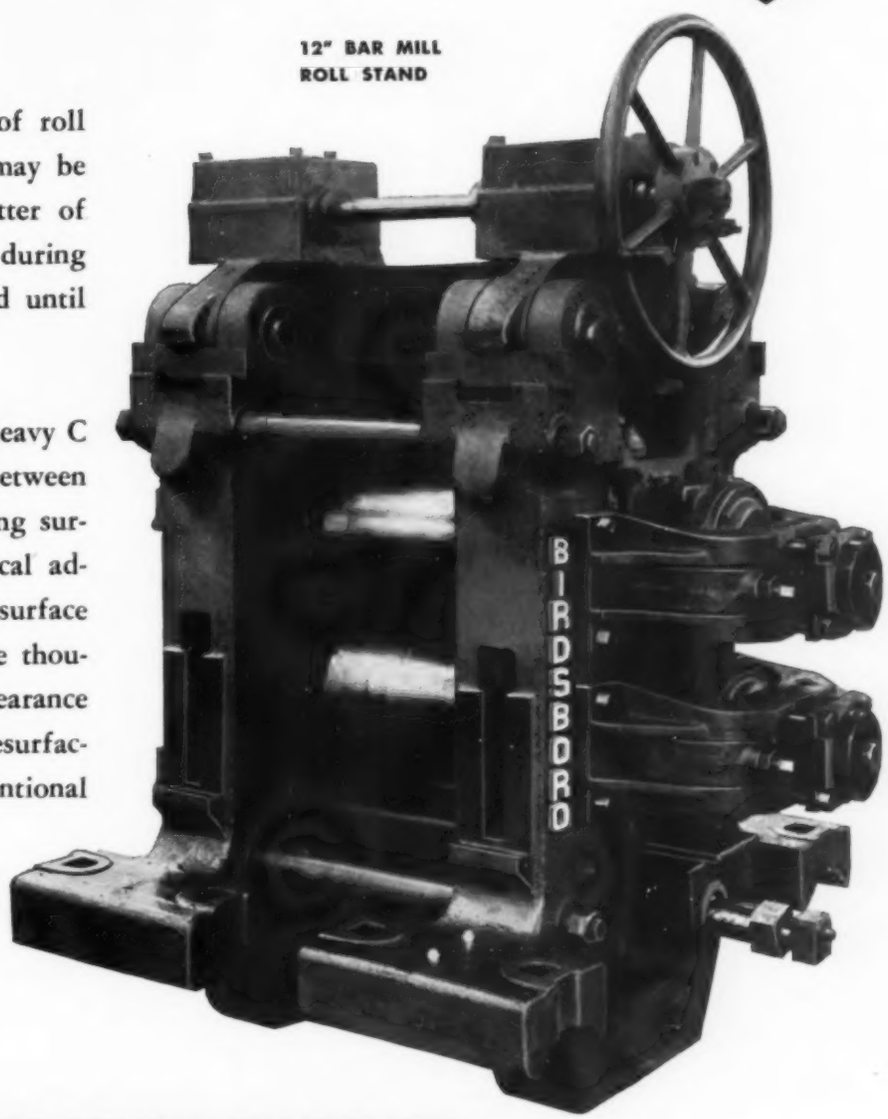
▲ RFC granted West Virginia Steel and Manufacturing Co. a $3,750,000 loan for steel plant machinery and equipment.

New BIRDSBORO Development

for Easy, Quick and Accurate End Roll Adjustment

Patented tilting caps permit changing of rolls through top of housing without disassembling end roll adjustment and with no loss in housing rigidity.

12" BAR MILL ROLL STAND



- Roller bearing locked to end of roll in totally enclosed housing . . . may be changed from roll to roll in matter of minutes . . . may be left on roll during dressing . . . need not be changed until roll is discarded.

Bearing housing held securely by heavy C clamps . . . no point contact between housing and clamp . . . self-aligning surface contact bearing permits vertical adjustment without wear of clamping surface . . . axial adjustments made to the thousandth of an inch . . . clamping clearance freely set and locked, eliminating resurfacing and grinding required by conventional locking devices.

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STEEL FOUNDRY & MACHINE CO.

Birdsboro, Penna.

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Designers and Builders of:
Steel Mill Machinery • Crushing Machinery • Rolls
Hydraulic Presses • Special Machinery • Steel Castings

Offices in
BIRDSBORO, PA. AND PITTSBURGH, PA.

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F·E·I

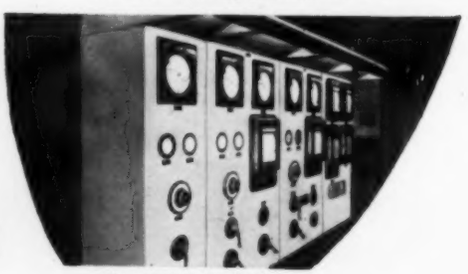
Breaking Tonnage Records
on SLABS, BILLETS, BLOOMS

Leading steel mills are going modern to the "nth" degree in order to meet today's demand for greater tonnage! Reports from users of F.E.I.'s modern Continuous Reheating Furnaces indicate consistently better results, *setting new records for tonnage*. All F.E.I. furnace installations are complete and co-ordinated. Patented automatically controlled combustion system guarantees the last word in *performance!*

F.E.I. serves industry both here and abroad . . from plan to production . . Open Hearth Furnaces, Soaking Pits, Continuous Reheating Furnaces, Forging Furnaces, Annealing and Normalizing Furnaces, Galvanizing Furnaces and complete heating lines for all kinds of armament — guns, armor plate, shells, etc.

View of slab entrance end.

Side view showing patented Burners.



Instrument panel of automatic controls.

F E I Furnace Engineers Inc.

F.E.I. BUILDING • 1551 W. LIBERTY AVE. • PITTSBURGH 16, PA.

AFFILIATES — *Great Britain:* Salem Engineering Co., Ltd., Milford near Derby, England; *France, Belgium, Holland, Luxembourg and Italy:* Heurtey & Co., 38 Av. G. Mandel, Paris XVI, France.

8

Industry News...

REPUBLIC STEEL CORP. RECEIVES FIRST SHIPMENT OF WEST AFRICAN ORE

▲ The first shipment of West African iron ore to reach the United States arrived at Baltimore June 22, 1951 from Liberia, West Africa, when the SS Simeon G. Reed under charter to the Farrell Steamship Line docked with a cargo of 10,000 tons.

The iron ore is from the Bomi Hills deposit, 43 miles inland from Monrovia, the capital and chief seaport of Liberia. A railroad, the first in the country, connecting the mine with Monrovia, was rushed to completion to speed up ore shipments.

On its arrival in Baltimore the ore was loaded immediately for consignment to Republic's plants in Cleveland, Warren, Youngstown, Canton and Massillon.

With an iron content up to 70 per cent as compared with iron content averaging 51 per cent for Lake Superior ores, the Liberian product approaches pure iron oxide which contains approximately 71 per cent of iron and 29 per cent oxygen.

Because of the high iron content and the fact that this is a lump ore, it will be used directly in the open hearth furnaces to assist in carbon reduction. Since oxygen and carbon have a great affinity for one another, the three or four per cent carbon present in the early stages of steelmaking readily combines with the oxygen in the iron ore. Carbon gases which result pass off into the exhaust flues leaving free iron which supplements the iron already in the molten bath.

While no fixed estimate of the amount of ore available has yet been made, millions of tons are lying on the slopes of Bomi Hills and need only be cleaned, sorted and loaded into cars.

The ore deposit is in the form of a cliff almost a mile long and from 30 to 100 feet high. Over the ages the face of the cliff has weathered and broken off leaving a huge continuous pile of ore at its foot in pieces ranging in size from a marble to a box car.

The ore is transported to Monrovia by the new 43-mile railroad where an ore loading dock is now nearing completion. In Baltimore it will be unloaded at the $5,000,000 ore terminal recently put into service by the Baltimore & Ohio Railroad.

For the next several months the iron ore will be shipped in chartered cargo vessels but sometime early in 1952 the first of a fleet of 23,000-ton ore carriers, built for the Liberian Navigation Co., of which Republic is half owner, will take over.

WEAN GETS CONTRACT FOR PICKLING LINE

▲ Wean Engineering Co., Inc. has been awarded contracts by the United States Steel Co. for a continuous strip pickling line, a continuous strip cleaning line, a continuous electrolytic tinning line, and a combination temper mill and shear line. These facilities are for the company's new Fairless works located near Morrisville, Pa.

The high-speed pickling line, which will have the largest capacity of any similar unit in the world, will remove oxide formed during the rolling operation in the hot strip mill. This oxide coating must be removed before cold rolling. Oil remaining on the surface of the steel coils after cold rolling will be removed by the continuous strip cleaning line, through which cold reduced strip will be fed at speeds up to 2000 fpm.

The electrolytic tinning line, complete with auxiliary facilities, will be the major unit to produce tin plate at the Fairless works and is designed to handle coils weighing 30,000 lb and containing five or six miles of steel strip in each coil. The coils will be electrolytically tinned and automatically cut to size as they pass through the line.

The combination temper mill and shear line will receive coils from the hot strip mill for temper rolling under

DAM TO SPEED RIVER BARGE TRAFFIC

New riverward lock at Dam No. 2 on the Monongahela River near Pittsburgh, Pa., was opened officially on June 1. The lock chamber is 360 ft long by 56 ft wide. Second phase of the reconstruction program by the Army Corps of Engineers and the contracting division of Dravo Corp. will be construction of the landward chamber 110 ft wide by 720 ft long. The lock then will accommodate increasing barge traffic on the busy river.

THE AMERIGEAR* FULLY CROWNED TOOTH

*Trade Mark Registered

A MAJOR IMPROVEMENT IN GEARING

A fundamental improvement on a proven design now incorporated in Amerigear Couplings

A fundamental improvement in gear tooth design that practically eliminates all "end tooth and tip" contact, and provides greater freedom of axial movement. It is the first gear tooth on which all the load is carried on strong flanks rather than tooth edges. It reduces backlash to a minimum and permits greater load-speed capacity. The result of a program of continuous research and development, keyed to achieve higher efficiency in the transmission of power, the *Amerigear Fully Crowned Tooth* may be utilized in solving a wide range of special power transmission problems other than those common to gear-type couplings in which it is now incorporated. A folder on the Amerigear Fully Crowned Tooth is available on request.

AMERICAN FLEXIBLE COUPLING COMPANY

Originator of the Amerigear Fully Crowned Tooth • Sales Offices in Principal Industrial Centers

ERIE, PA., U. S. A.

AFFILIATE OF J. A. ZURN MFG. CO. • ERIE, PA., U.S.A.

tension, side trimming and cutting to length for shipment. Additional facilities will also be provided for secondary slitting, temper rolling, and recoiling.

FURNACE IS REBUILT IN 120 WORKING DAYS

▲ A new record in blast furnace rebuilding was set by Koppers Co., Inc., June 7 as the new No. 5 blast furnace at the Ohio works, Youngstown, Ohio, of United States Steel Co. was blown in 120 working days after the old furnace was blown out.

Constructed by the Freyn department of Koppers' Engineering and Construction Division, the new furnace has a hearth diameter of 25 ft and a capacity of 1100 net tons of iron per day. The old 21-ft hearth diameter furnace had a capacity of 776 net tons per day.

Forty-one days were required to dismantle the furnace and 79 days to rebuild. Work on the project was begun January 23, 1951.

In addition to enlarging the foundation and constructing new brickwork and the new steel shell, the Freyn department also installed a new skip bridge and new hoisting and charging equipment on the furnace. New brickwork in the four stoves of the furnace as well as a new dust catcher, gas washer, precipitator, and gas and blast mains were included in the rebuilding job. Only a portion of the original foundation and the shells of the old stoves were retained.

WIRE FIRM TO REPLACE DULUTH COKE OVENS

▲ American Steel & Wire Co. has announced plans for removing and rebuilding another portion of the old coke ovens at the Morgan Park plant of its Duluth, Minn., works.

This program will complete the replacement of the old coke ovens which have been in service since the plant was built over 35 years ago. The replacement of these worn out units will be made gradually by taking a portion of the old ovens out of service, razing them, and on the same site replacing them with new units. The entire job will take more than a year to complete.

In 1949 the Duluth plant began its coke plant modernization program when it replaced a portion of the coke ovens built in 1913. This work will

STOP COSTLY SHUTDOWNS DUE TO COUPLING FAILURE

THE PROVEN GEAR-TYPE COUPLING WITH FULLY CROWNED TEETH

Teeth designed and formed to accomplish tight fit on the crown, as well as on the flanks. Teeth that reduce backlash to a minimum and operate with relatively constant stresses on all teeth simultaneously in all positions; provide freer axial movement; prevent end tooth and tip contacts; assure quiet performance; enlarge load and speed capacity, and give so much more protection than ever before against downtime. These advantages, plus thrust compensation, and correction for angular and lateral misalignments give relief from coupling failure grief. Amerigear Couplings are available for all standard shaft sizes and the widest range of speed and load capacities. Catalog available on request.

AMERICAN FLEXIBLE COUPLING COMPANY

Originator of the Amerigear Fully Crowned Tooth
Sales Offices in Principal Industrial Centers

ERIE, PA., U. S. A.

AFFILIATE OF J. A. ZURN MFG. CO.

Manufacturers of the original "Oldham Type" American Flexible Coupling.

AMERICAN FLEXIBLE COUPLING CO., ERIE, PA., U. S. A.
Please send me further information regarding AMERIGEAR COUPLINGS with the Fully Crowned Teeth and Catalog No. 501.

Name ..... Title .....
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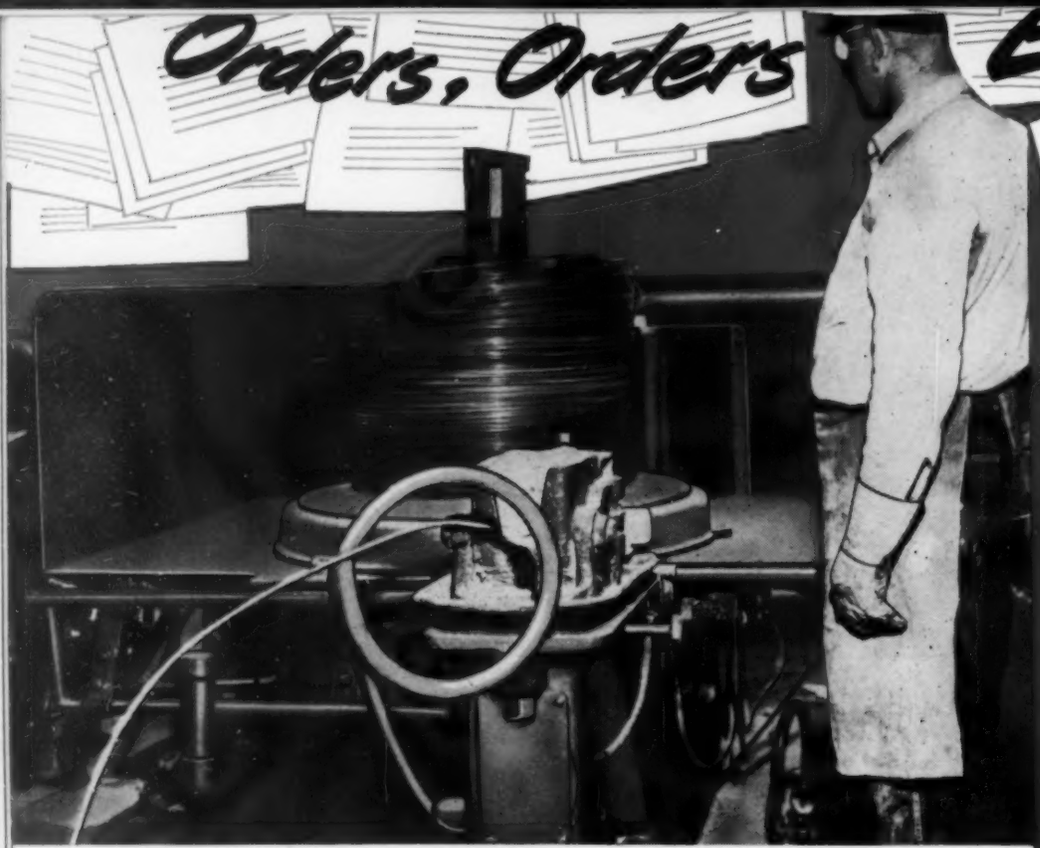
Please attach to your business letterhead. Dept ISE

Orders, Orders Everywhere!



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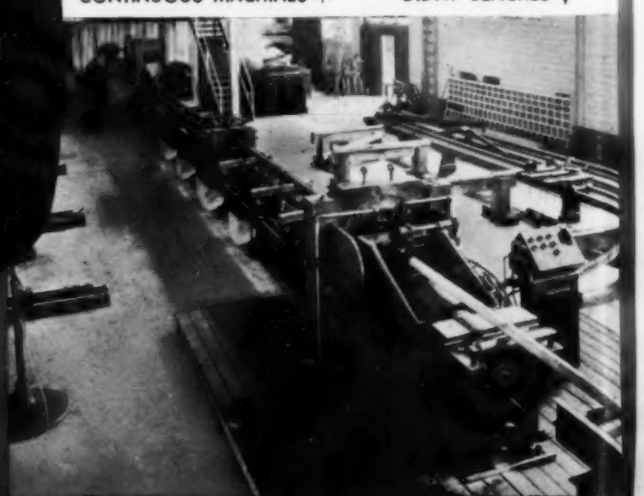
MOTOBLOC® ↑ MOTOBLOX® ↓

CONTINUOUS MACHINES ↑ DRAW BENCHES ↓



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COLD DRAWING MACHINERY

The best help you can have in meeting today's great demands for cold drawn products comes through the fast, flexible performance of today's VAUGHN *Equipment! Let us detail the facts, in relation to your present production problems.*

The VAUGHN MACHINERY CO., Cuyahoga Falls, Ohio, U. S. A.

COMPLETE COLD DRAWING EQUIPMENT . . . Continuous or Single Hole . . . for the Largest Bars and Tubes . . . for the Smallest Wire . . . Ferrous, Non-Ferrous Materials or their Alloys.

complete the plant's coke oven replacement program.

Construction will be made under the direction of Koppers Co. which has been awarded a contract for the work.

$900,000 PROGRAM FOR CRUCIBLE AT SYRACUSE

▲A $900,000 program to expand steel making and processing facilities of the Sanderson-Halcomb works, Crucible Steel Co. of America, Syracuse, N. Y., has been announced.

An additional electric furnace is being installed in the melt shop of the plant. This unit adds to the plant's melting capacity for alloy, super alloy and other special purpose grades.

The wire mill of Sanderson-Halcomb works is being further expanded by auxiliaries to speed and improve cold finishing operations on coils, small bars and precision-finished wire products. The mill produces these products from a wide variety of Crucible grades. This equipment includes copper coating apparatus for coils, straightening machines, continuous annealing furnace, additional centerless grinding and coil grinding machines.

In the bar finishing department, additional installations include a big circular saw, centerless grinding machine for bars, and polishing equipment.

Expanded capacity for cogging will be obtained by additional ingot heating pits. These are auxiliary to cogging mills and to a new 1000-ton press already in operation.

There will be expanded facilities for billet and bar annealing. The electric power distribution system of the plant is being improved.

EIGHTH OPEN HEARTH OPERATING AT KAISER

▲ Kaiser Steel's eighth open hearth furnace began operations recently at Fontana, Calif., with the charging of materials for the first 225-ton "heat" of steel. The new open hearth will raise Kaiser Steel's rated capacity to 1,380,000 tons of ingots annually, an increase of 15 per cent over the previous annual ingot capacity of 1,200,000 tons.

Operation of this newest open hearth furnace marks another important phase in the expansion of

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ON RUN-OUT TABLES TOO..
LOVEJOY L-R
FLEXIBLE COUPLINGS
THREE YEAR
MAINTENANCE-FREE
SERVICE RECORDS
Eliminate costly shut-downs and break-downs due to coupling failures on run-out tables and other equipment with Lovejoy Flexible Couplings. They are designed to correct mis-alignment without vibration, backlash or surge. Free-floating load cushions are suspended between heavy metal jaws. No shut-downs for changing cushions, which last two to five years. No lubrication ever needed.
WRITE FOR COMPLETE CATALOG AND QUICK-FINDING SELECTOR CHARTS
LOVEJOY FLEXIBLE COUPLING CO.
5093 WEST LAKE STREET
CHICAGO 44, ILLINOIS

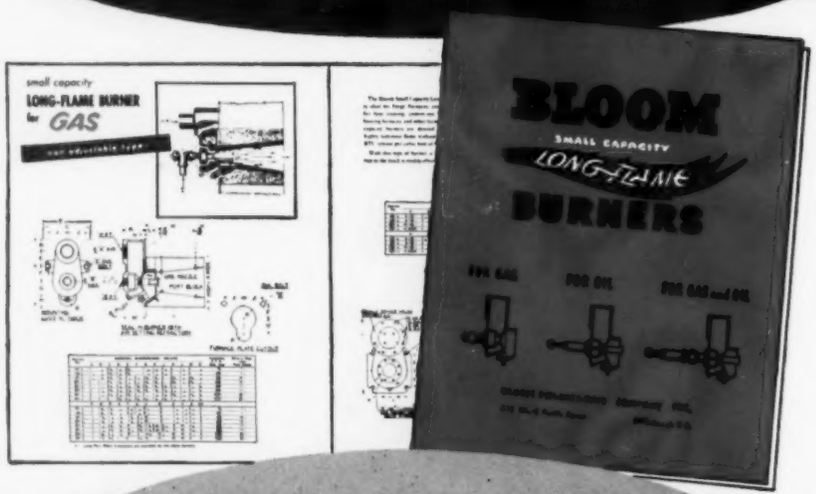
capacity of the West Coast's only integrated steel plant. The rated capacity of 1,380,000 ingot tons annually represents an increase of more than 100 per cent over the amount of steel produced in 1944, the peak war year.

Other facilities designed to increase the output of steel which have been completed or are nearing completion include two additional soaking pit furnaces, doubled facilities for stripping ingot molds, and increased handling capacity in the blooming mill.

Still under construction as the major part of a $24,500,000 expansion program is the tinplate mill, which will have an annual capacity of 200,000 tons of electrolytic and hot dip tinplate. Deliveries of mill equipment are scheduled to begin in the fall of 1951 and operation of the tin mill itself is expected to commence early in 1952.

USE THE ENGINEERING MART

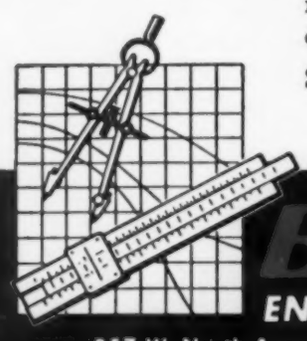
GET THIS NEW BULLETIN!



For Flexibility, Efficiency and Faster Heating in Industrial Furnaces—
BLOOM Long Flame BURNERS

You should have this informative data bulletin, describing the complete line of Bloom LONG FLAME Burners—for gas, oil and gas-and-oil. The bulletin describes the various sizes and types of burners, gives typical installation drawings, shows important dimensions for each size.

Send for your free copy today.



BLOOM ENGINEERING CO., INC.
857 W. North Avenue Pittsburgh 33, Pa.

BRAZILIAN FIRM NAMES SALES AGENCY FOR U. S.

▲ Vale do Rio Doce Agency Co. has been appointed to act as sales representative for the Companhia Vale do Rio Doce, Rio de Janeiro, Brazil. This new agency company is formed in conjunction with Deltec S.A., Rio de Janeiro; Wardell, Hatch & Co., Inc., New York; and Messrs. Edwin S. Webster, Jr., Kurt Orban, and Henry H. Patton of New York, under a contractual relationship with the mining company in Rio. It is located at 63 Wall Street, New York, N. Y.

The company will engage in the selling of Itabira iron ore, mined by the Companhia Vale do Rio Doce in its Minas Gerais properties, Brazil. The agency company in New York will also render technical advisory service for the American steel industry regarding the characteristics and results obtained by the use of this ore.

Itabira ore has long been known as unusually outstanding for use in open hearth furnaces both as a charge ore and a feed ore. In addition to its high Fe content of 68½-70 per cent, it contains only traces of silica and phosphorus. Its moisture content runs extremely low at less than 1 per cent. Open hearth operators have experienced a more consistent and steady carbon reduction graph plus savings in heat time of up to two hours per heat as compared with other ores used. Under conditions of maximum capacity production it has an unsurpassed value for companies with open hearth furnace operations.

FOUNDATION FIRM IS NEWLY ORGANIZED

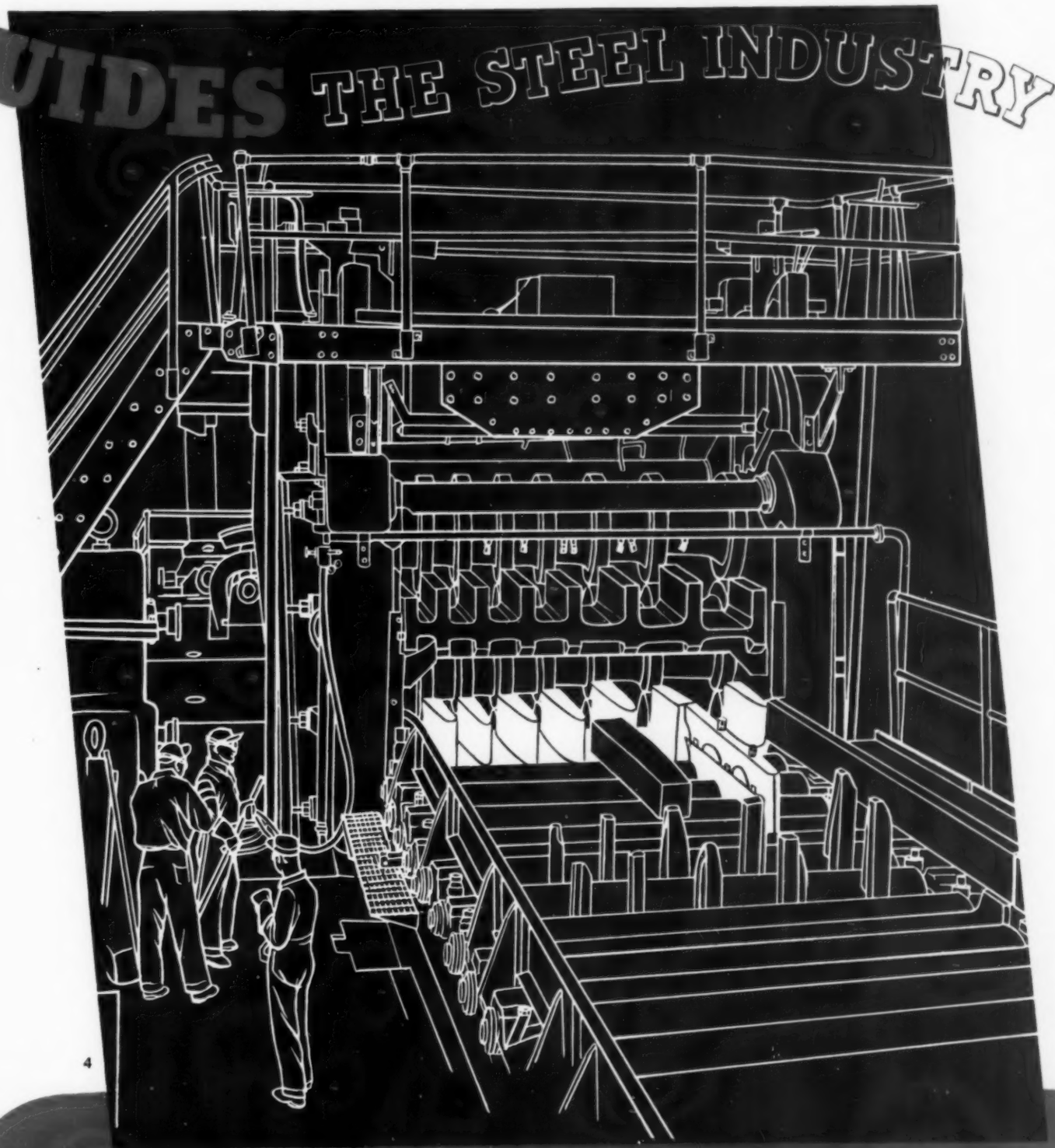
▲ Formation of the Franki Foundation Co., which will engage in engineering and installing foundations for industrial and commercial construction, and for public works, was announced recently by Arthur J. Bulger, newly elected chairman and president of the organization.

Members of the board of directors of Franki Foundation Co., in addition to Mr. Bulger, are Joseph Becker, E. A. Berry, George M. Carvlin, Leon A. Fraikin, Edgar Frankignoul, and Alfred Putzeys.

Other officers of the new company, which has established general headquarters at 436 Seventh Avenue, Pittsburgh, Pa., are: George M.

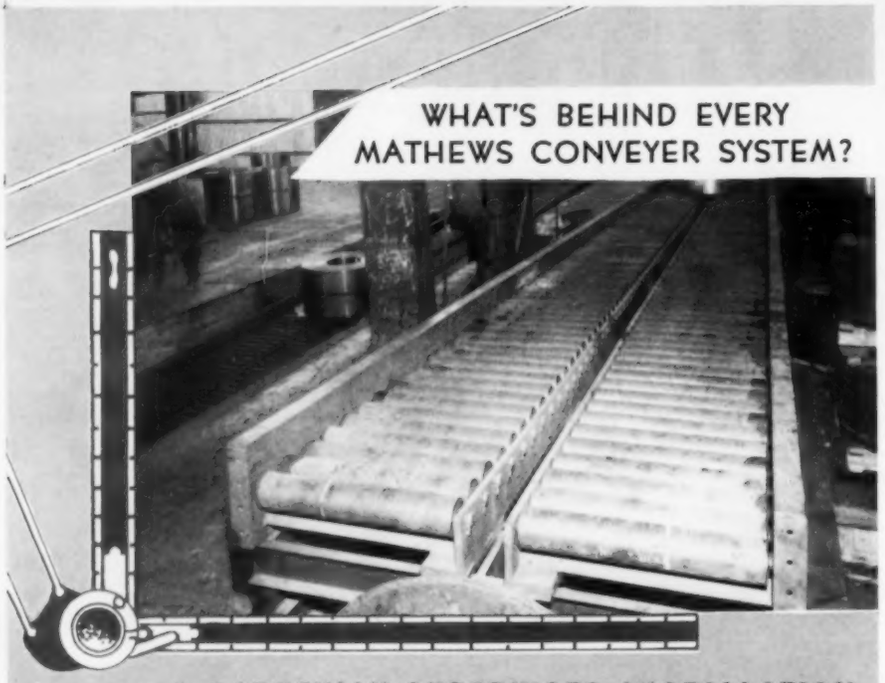
TRANTINYL

GUIDES THE STEEL INDUSTRY

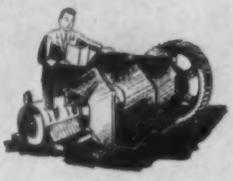


Wear-Resistant Tools for the Rolling Mill Industry

Youngstown Alloy Casting Corp. . . . Youngstown, Ohio



A CAREFULLY SUPERVISED INSTALLATION



● Behind every Mathews Conveyer System you find many factors . . . cooperative planning, a balanced engineering staff, sound engineering practices and a carefully supervised installation.

Supervising installations means following through. Men especially trained for this type of work are on the job, seeing that every piece of the equipment gets into place, and making all the hours of engineering time and production effort that have gone into the system pay off in smooth operation and efficiency.

Supervising installation is a vital part of Mathews complete service. Experience has proved that a well-engineered system, with all its integral parts carefully built, deserves the best attention to erecting details.

The Mathews people will take the responsibility for making your conveyer system work perfectly. Engineering, manufacturing and installing conveying equipment has been their only business since 1905.

That's why you can be sure, "If it's Mathews equipment, it has to be right."

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GENERAL OFFICES . . . . . *Mathews Conveyer Company*
ELLWOOD CITY, PENNSYLVANIA

PACIFIC COAST DIVISION . . *Mathews Conveyer Company West Coast*
SAN CARLOS, CALIFORNIA

CANADIAN DIVISION . . . . . *Mathews Conveyer Company, Ltd.*
PORT HOPE, ONTARIO

Carvlin and Leon A. Fraikin, vice-presidents; John M. Crimmins, secretary; and E. B. Shuck, treasurer.

Employing an exclusive method of construction, the displacement caissons in which the new company will specialize are installed "from the bottom up," according to Mr. Bulger.

In describing the method of installation, Mr. Bulger said that a plug of concrete placed at the bottom of a steel casing is driven into the ground by blows from a solid ram weighing from two to four tons.

When the desired bearing soil strata, or rock, is reached small quantities of concrete are successively driven out of the casing by the ram to form and enlarged base. As the casing is removed, the shaft is solidly rammed with dry concrete.

REPUBLIC BUYS TROY, N. Y. COKE-PRODUCING UNITS

▲ Niagara Mohawk Power Corp. has sold the coke-producing facilities at its Troy, N. Y. coke and gas plant to Republic Steel Corp. Niagara Mohawk Power Corp. is in the process of introducing natural gas to replace the manufactured gas in the area served by the Troy plant. The transfer of the property will become effective when the natural gas becomes available for distribution. Niagara Mohawk will retain its water gas facilities at Troy in readiness to supplement the natural gas supply if and when needed.

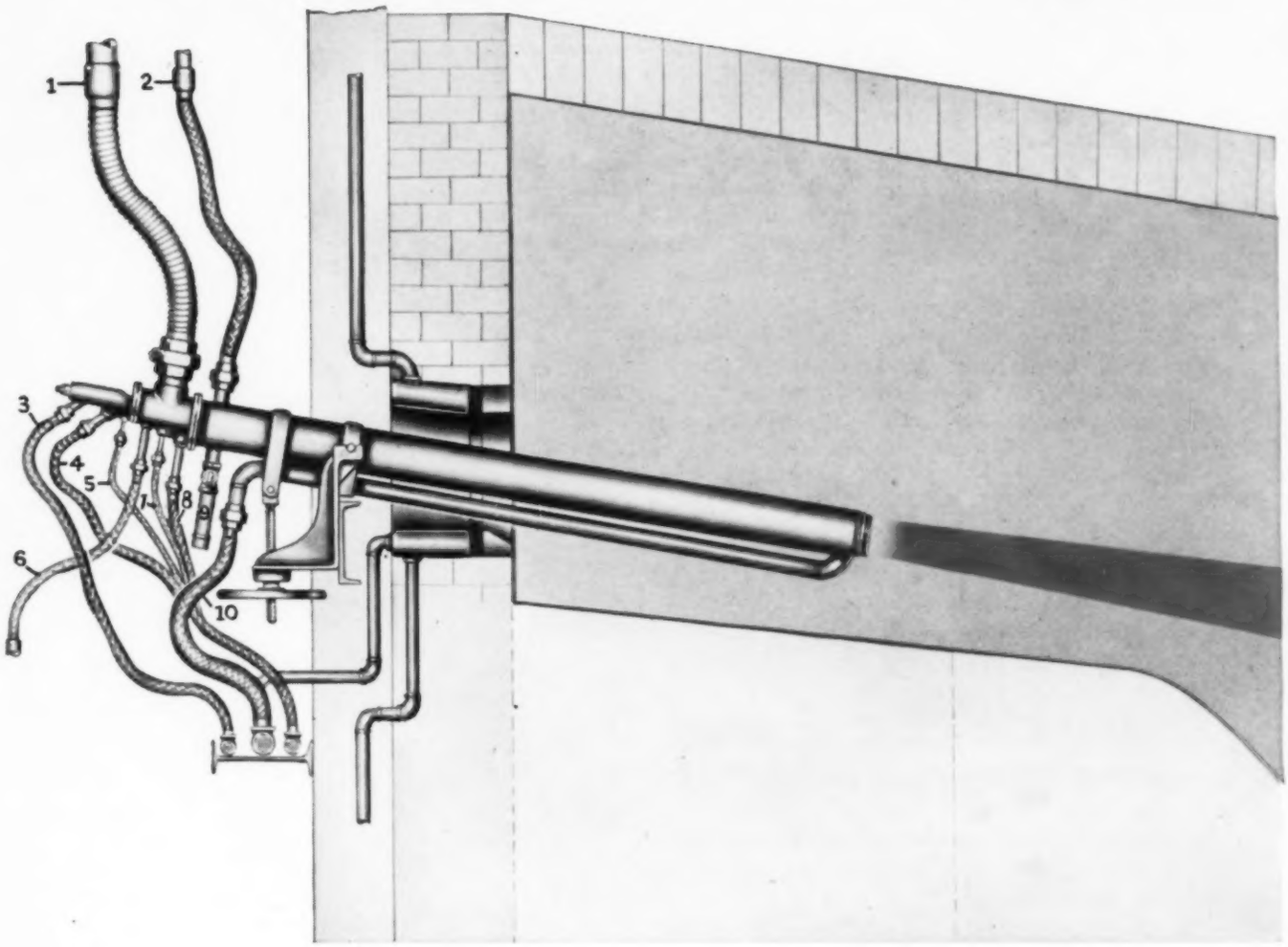
The coke manufacturing facilities of the Troy plant adjoin the Republic Steel blast furnace at Troy.

Coke from the Troy plant has been continuously purchased by Republic for use in its adjoining blast furnace operations. By the transfer, Republic will now have its own coke plant in addition to its blast furnace for the production of its high quality pig iron.

SCHOLARSHIPS ARE ESTABLISHED BY WEAN

▲ The Raymond John Wean Foundation has established two partial scholarships, one at University School, Shaker Heights, Cleveland, Ohio, a preparatory school for boys, and the other at Carnegie Institute of Technology, Pittsburgh, Pa. The board of administrators of the foundation has asked each of the schools to give consideration to applicants for scholar-

INCREASE TONNAGE



CROWE Artillery Water Cooled Burners

Years of successfully firing all fuels used in open hearth furnaces assure success in producing increased tonnage, with less fuel by using Crowe Artillery Water Cooled Burners.

Oxygen, Gas, and Oil are used in combination, or separately, in the burner shown. Our many years in the business have taught us the "know how" necessary to handle fuels to produce the best results with the minimum amount of fuel.

Crowe Burners are custom made to fit your furnace conditions.

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THE CROWE ENGINEERING COMPANY

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ships in the following order: First: to applicants who are children of employees of any one of the Wean companies; Second: to applicants who are residents of Trumbull or Mahoning Counties in the state of Ohio; Third: to applicants from any other area.

Scholarship applications on the part of those interested in Carnegie Institute of Technology should be addressed to: Dr. John Daniels, chairman of admissions, Carnegie Institute of Technology, Pittsburgh 13, Pa.

Scholarship applicants for University School should address their applications to: H. L. Cruikshank, head master, University School, Claythorne & Brantley Roads, Shaker Heights 22, Ohio.

RUST ANNOUNCES MANY NEW CONTRACTS

▲ Six new batteries of 3-hole soaking pits will be built by Rust Furnace Co. at the Indiana Harbor, Ind., works of Youngstown Sheet & Tube Co. The new pits will be of the recuperative type with top diagonal firing of mixed gas, with oil as an alternate fuel. They will serve the new No. 2 blooming mill. Each hole is designed for a maximum charging capacity of 14 large-size ingots.

Three slab reheating furnaces are also being rebuilt at Republic Steel Corp.'s Corrigan-McKinney works, Cleveland, Ohio, by Rust Furnace Co. The rebuilt furnaces will supplement a new 100-ton capacity, triple-fired, zone-controlled Rust slab heater. To maintain maximum production, rebuilding of the older furnaces is being conducted so that only one unit is out of operation at a time.

Rust Furnace is currently working on design and engineering changes to increase capacity of a slab heating furnace for South African Iron and Steel Industrial Corp., Ltd., at Pretoria, South Africa. Rebuilding will increase the capacity of this furnace to 100 tons per hour. It was previously constructed by Rust in 1941.

Rust Engineering Co. is constructing a water treatment plant at the South Side works of Jones & Laughlin Steel Corp., Pittsburgh, Pa., to replace one which will be razed to make room for the new No. 4 open hearth shop. The new water treatment plant will be capable of handling about 4000 gpm of raw water. It will cold process water drawn from the nearby Monongahela River for use throughout the Pittsburgh works.

THIS IS THE TIME TO SAVE PICKLING ACID!

Here are some ways to pickle more steel with less acid:

1. IMPROVE THE EFFICIENCY OF YOUR PRACTICE

Use every available pound of acid before dumping, by:

a. Operating baths until more than the usual amount of iron accumulates,
b. Stopping the additions of acid sooner than usual,
c. Offsetting the slower pickling by raising bath temperature to boiling,
d. Lengthening pickling time for last one or two batches.

Do not, if possible, dump bath with as much acid content as previously. Dump only when bath fails to work after above recommendations have been followed.

2. IMPROVE THE CHEMICAL EFFICIENCY OF YOUR PICKLING

Utilize every available pound of acid before dumping, by:

a. Increasing the proportion of "RODINE"® in the bath up to 1% by volume of the acid.

The increased amount of "RODINE" will:

a. Save the acid now needlessly wasted dissolving good metal,
b. Retard from build-up, thus saving acid by reducing number of times tanks must be dumped.

Write for further information on saving pickling acids.

STANDARD PICKLING PRACTICE THE WORLD AROUND — CHEMICALS ACP PROCESSES

AMERICAN CHEMICAL PAINT COMPANY

AMBLER, PA.

CANADIAN STEEL FIRM BUILDS O. H. SHOP

▲ Steel Co. of Canada, Ltd., is building a four furnace open hearth shop at Hamilton, Ontario, Canada.

The ends of the furnaces will be of basic construction and the main roof of silica brick. Each furnace will have a nominal capacity of 250 net tons, with a maximum capacity of 275 net tons. The shop is expected to be in operation in the fall of 1952.

PITTSBURGH COKE ADDS NEW BLAST FURNACE

▲ Pittsburgh Coke and Chemical Co. has awarded Koppers Co., Inc., contracts for construction of a new blast furnace at its Pittsburgh, Pa., Neville Island plant. The new blast furnace will be designed and constructed by the Freyn Engineering department of Koppers Engineering and Construction Division. It will have a hearth diameter of 22 ft and will be capable of producing approximately 850 tons of pig iron per day. Pittsburgh Coke and Chemical now has one other blast furnace of approximately the same size, hence the new furnace will double its capacity.

Engineering work already has started on the new installation which will be completed as rapidly as possible.

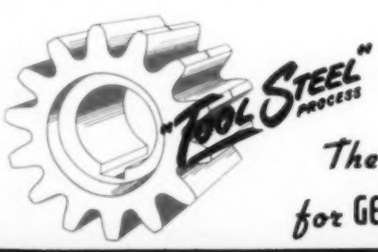
. . . For all Cold Processing Operations

Cold rolling and cold processing rolls made by "Tool Steel" have proven that they give the desired finish at the **lowest cost per ton!**

"Tool Steel" manufactures both the homogeneous rolls for cold rolling and the case hardened "Tool Steel" Process rolls for other cold operations. Thus "Tool Steel" offers you **the proper roll for any cold operation.**

"Tool Steel's" heat treating "know-how" (since 1909) will produce for you the very best rolls for your service!

Let "Tool Steel's" Representatives and Engineers show you how you can save money by using "Tool Steel" Rolls.



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for GEARS • PINIONS • SPROCKETS • WHEELS *and other* HARDENED PRODUCTS

THE TOOL STEEL GEAR & PINION CO.

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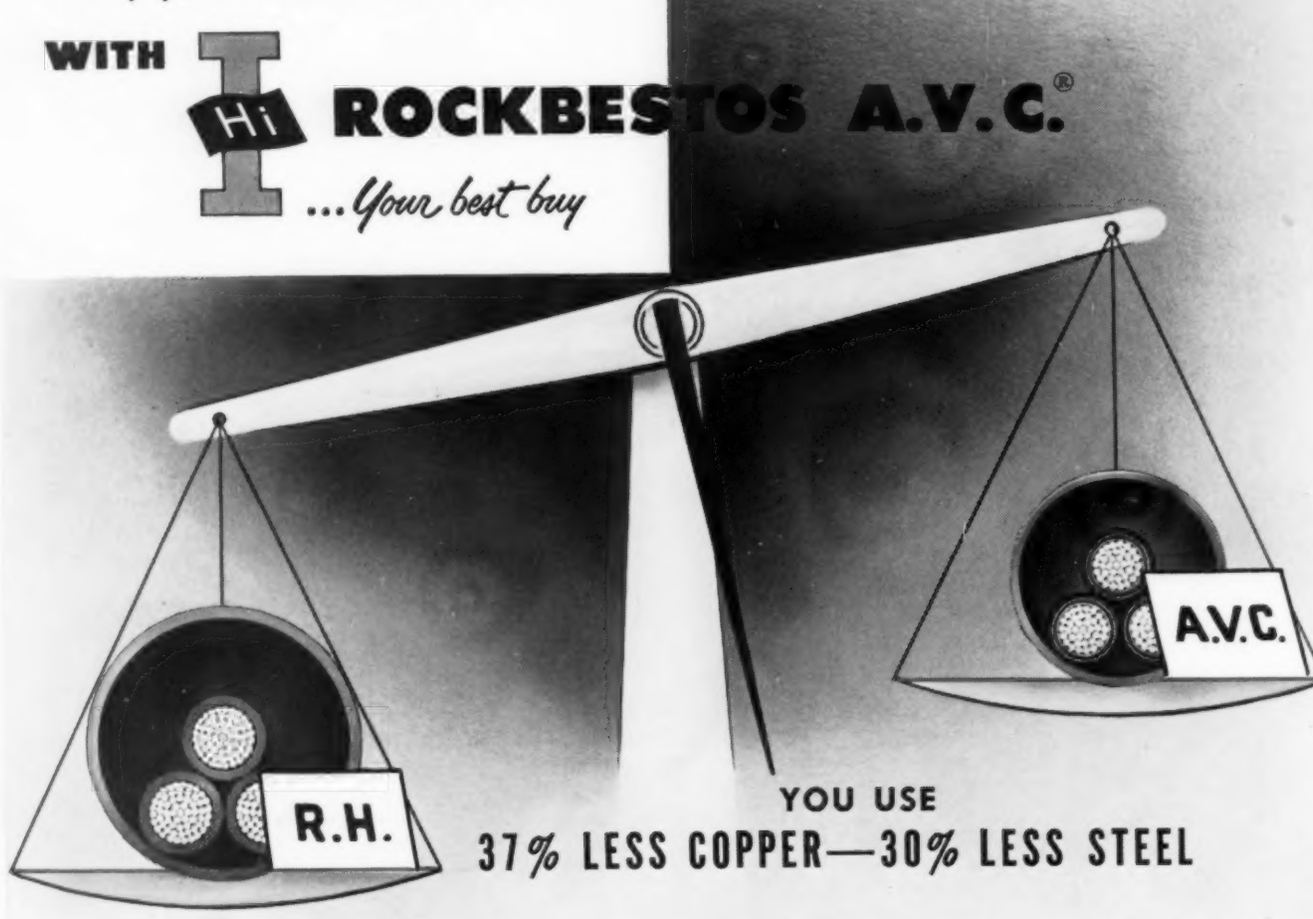
Conserve Critical Copper and Steel

WITH Hi ROCKBESTOS A.V.C.®

...Your best buy



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37% LESS COPPER—30% LESS STEEL

For a 430 ampere load, 3Ø, 3 wire, 40°C Ambient, 100' run—NEC chapter X

		TYPE RH	TYPE A.V.C.	
CONDUIT	SIZE	4 inch	3 inch	A saving of 327 lbs. of steel
	WEIGHT	1089 lbs./100'	762 lbs./100'	
CABLE	SIZE	800 MCM	500 MCM	A saving of 277.8 lbs. of copper
	WEIGHT	741 lbs./100'	463.2 lbs./100'	

Write for booklet "Rx for a Building with Hardening of the Arteries."

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...Your best buy

ROCKBESTOS PRODUCTS CORPORATION

NEW HAVEN 4, CONNECTICUT

Chicago, Detroit, Pittsburgh, St. Louis, Cleveland, New York, New Orleans, Los Angeles, Oakland, Calif.

ARMCO GRANTS LICENSES TO ALLEGHENY LUDLUM

▲ Allegheny Ludlum Steel Corp. has been granted a license by Armco Steel Corp. to use its patents covering processes for the production of special types of electrical alloy steel sheets.

These grades of steel are used by electrical equipment manufacturers in producing transformers, generators, and other electrical equipment.

Armco, in 1933, was the first company to produce special electrical steel. It has continued to carry on research in this field since that date. One section of its extensive research laboratories is devoted exclusively to the development of new and improved types of special electrical steels.

Several patents are covered by the license. Two include improved methods developed by Armco for the removal of carbon from the steel and the formation of a glass-like film on the surfaces of the sheet. Others cover the application of inorganic coatings which provide a high degree of electrical insulation and do not deteriorate at elevated temperatures.

SHARON TAKES DELIVERY OF 18 DIESEL UNITS

▲ Sharon Steel Corp. took delivery recently on the first of 18 diesel powered yard locomotives that will modernize transportation in the company's Roemer works, Farrell, Pa., and Lowellville works, Lowellville, Ohio. The dieselization program will also include the purchase of four diesel cranes, and will cost a total of $1,784,100. It is expected that deliveries of the new power units will be spread over 1951 and 1952. The first locomotive, a 1200 hp yard switcher, goes into service in the Lowellville works. The complete program will include eight yard switchers of 800 hp, two yard switchers of 1200 hp and eight smaller open hearth units for use within the open hearth shops and in the mold yards.

The new locomotives and cranes will consign to the scrap heap 23 steam locomotives and 6 old cranes. The steam locomotives have seen many years of service in the mills. They will make their final contribution to the production of steel as they are cut up for scrap and charged into the open hearth furnaces.

The change to diesel equipment will greatly improve working conditions in certain buildings where smoke from locomotives has been a nuisance. In operation the oil burning units are favored for their economy, power, and freedom from maintenance problems.

Sharon Steel is also installing fuel oil storage tanks at both the Roemer works and at Lowellville to supply the new equipment. Spare parts and repair depots are also being established to maintain the equipment.

HANNA FURNACE GETS NECESSITY CERTIFICATE

▲ Hanna Furnace Co., Buffalo, N.Y., has been granted a certificate of necessity by the Defense Production Authority. The certificate covers a $12 million expansion program in Buffalo, which is expected to include enlargement of one existing furnace and the building of a new blast furnace.

Bulletins on instruments and control for 2 types of furnaces

HEAT TREATING FURNACES

A complete summary of Hays products applicable to processes such as annealing, brazing and calorizing. Scope includes various methods of firing (underfired, overfired, sidefired), fuel burned (gas, coal, oil), and type of furnace (continuous, rotary hearth, slab heating, etc.).

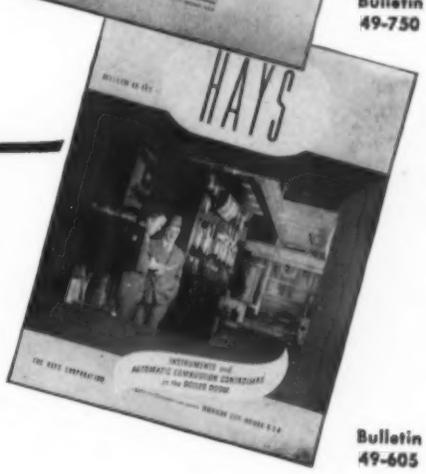
Hays complete line of draft gages, flow gages, and meters (for high and low pressure gases and liquids), portable gas analyzers and automatic CO_2 recorders are covered.

Bulletin 49-750

BOILER FURNACES

This bulletin summarizes applications of Hays centralized combustion control to chain grate, underfeed, spreader type, or lever type stokers; to attritia type, bowl type or ball bearing type pulverizers; to a wide range of oil burners including the rotary cup; and to a wide range of gas burners.

The Hays complete line of draft gages, flow gages, and meters (for high and low pressure gases and liquids), portable gas analyzers, automatic CO_2 recorders, and electronic type O_2 recorders are covered.



Bulletin 49-605

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THE **HAYS** CORPORATION

MICHIGAN CITY 13, INDIANA

combustion and industrial instruments and control

For any kind of metallurgical construction

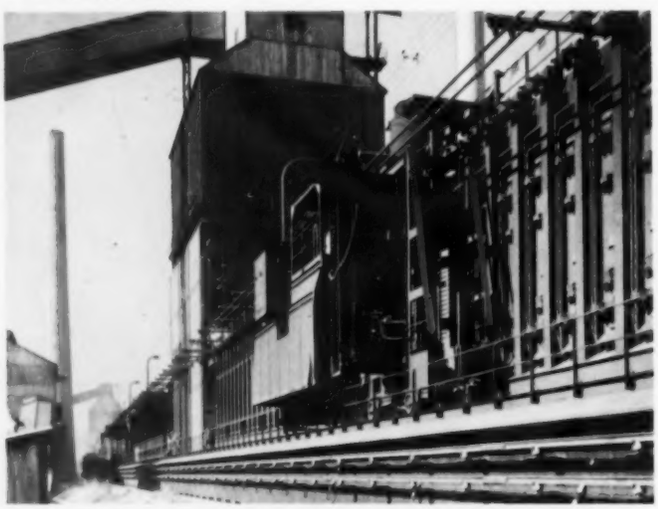
The installations pictured here give some indication of the scope of Koppers Metallurgical Engineering and Construction Services. Our Engineers and Management welcome the opportunity to consult with you.

ALL BRANCHES of the iron and steel industry *can count on Koppers* for comprehensive design, engineering and construction services, because Koppers Company is a specialist in the metallurgical field.

The Engineering and Construction Division of Koppers has long been recognized as a leader in the design and construction of coke-oven plants, auxiliaries and coal chemicals plants.

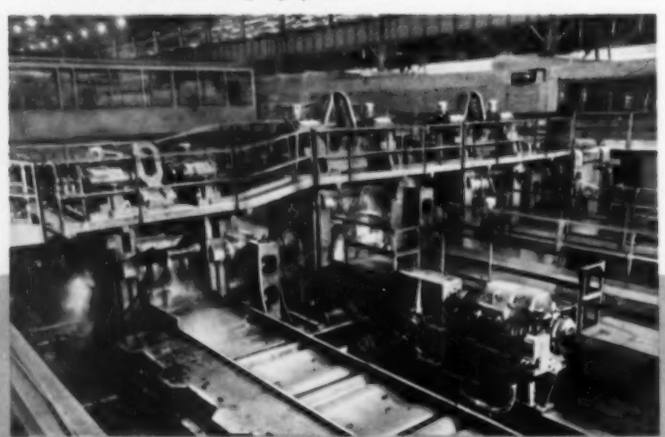
The Freyn Engineering Department of this Division specializes in the design and construction of blast furnaces, open-hearth furnaces and sintering plants . . . in the engineering of mills, power plants and other steel plant facilities.

Freyn-Designed and Constructed Sintering Plant. The sintering process permits *maximum* utilization of iron-ore fines and blast-furnace flue dust; also, it increases the pig-iron production of existing furnaces.



These 106 new Koppers-Becker Underjet Coke Ovens carbonize approximately 2,600 net tons of coal per day. Built in two batteries, they are equipped with Waste-Gas Recirculation and Blast-Furnace Gas Underfiring Equipment.

Freyn-Designed and Constructed Open-Hearth Furnaces.



Freyn-Designed Structural Mill and Traveling Tilting Tables.

This plant was constructed by Koppers for the recovery of ammonium sulphate, tar, light oil and pure benzol products from the carbonizing of 1,050 tons of coal daily.

YOU CAN COUNT ON KOPPERS!

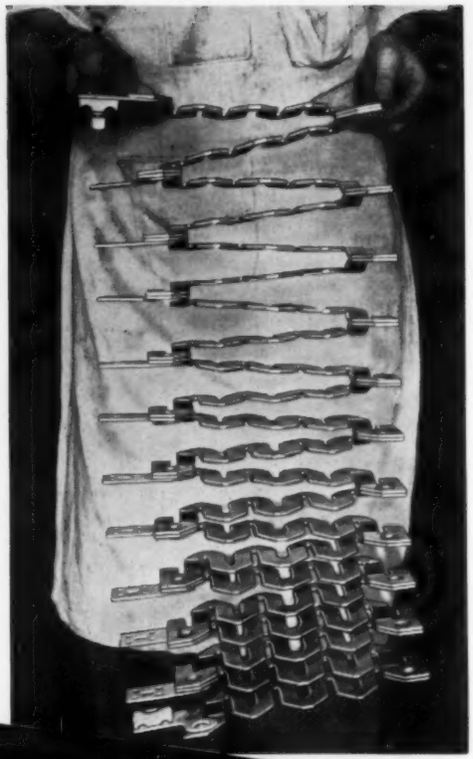
Typical Freyn-Designed and Constructed Blast Furnaces and Stoves.

KOPPERS *Engineering and Construction Division*

KOPPERS COMPANY, INC., PITTSBURGH 19, PA.

NO BURNING

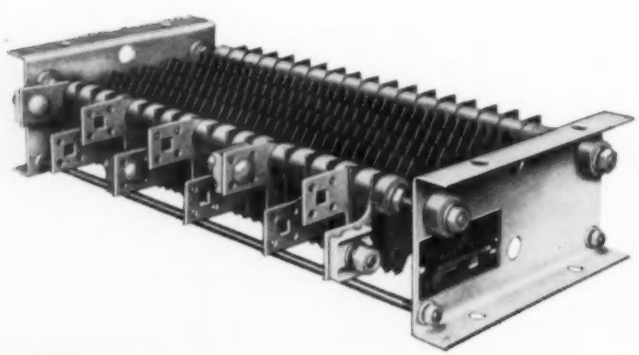
at Grid-eyes or at Tap-plates



Less Up-Keep with

TRADE MARK
E&M TAB-WELD PLATE RESISTOR
PATENT NO. 2,378,054

Resistors get little attention, because they are usually mounted overhead or in similar hard-to-reach locations. Clamping-nut pressure slackens under alternate heating and cooling. Formerly, under the reduced pressure, OHMIC value changed, burning occurred and often was *not* noticed until damage took its toll.



But—note how resistor troubles are now eliminated in the EC&M TAB-WELD design! The current-carrying path is continuous—and is *independent* of end clamping-nut pressure. Convenient tap-plates simplify tap-shifting—make possible small adjustments in resistance value, because plates are closely spaced. Also, these alloy-steel resistors are corrosion-resisting—and have negligible resistance-change between cold and maximum working temperatures.

SPECIFY EC&M BULLETIN 942-A TAB-WELD PLATE RESISTORS FOR CRANE AND MILL AUXILIARY CONTROL

THE ELECTRIC CONTROLLER & MFG. CO.
2698 EAST 79TH STREET • CLEVELAND 4, OHIO

... low resistance
...like INTERNATIONAL GRAPHITE ELECTRODES

INTERNATIONAL Graphite & Electrode CORP.

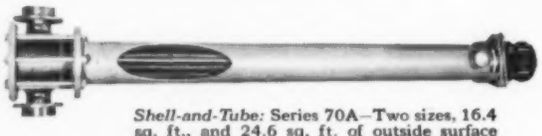
A SPEER CARBON COMPANY SUBSIDIARY

ST. MARYS, PENNSYLVANIA

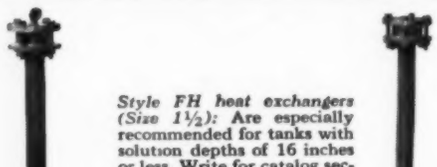
"KARBATE" BRAND IMPERVIOUS GRAPHITE HEAT EXCHANGERS *FOR ALL PURPOSES!*

The "Karbate" impervious graphite heat exchangers illustrated are used extensively as boilers, coolers, condensers, vaporizers, evaporators, heaters and absorbers in handling corrosive chemicals, either hot or cold. They *all* can be had in a complete size range. *All of them* offer the following advantages:

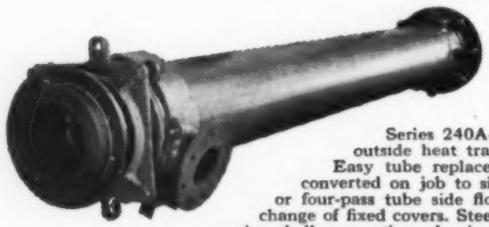
- **Highest heat conductivity rate of the practical corrosion-resistant materials.**
- **Highly resistant to corrosion by acids or alkalis, hot or cold.**
- **Freedom from corrosion scale, as compared to metals.**
- **Immune to thermal shock.**
- **No contamination of product.**
- **Strong and easy to install and maintain.**



Shell-and-Tube: Series 70A—Two sizes, 16.4 sq. ft., and 24.6 sq. ft. of outside surface area respectively. Tubes easily replaced in the field. Interchangeable single and double-pass construction.



Style FH heat exchangers (Size 1½): Are especially recommended for tanks with solution depths of 16 inches or less. Write for catalog section S-6750.



Series 240A—70.6 feet of outside heat transfer surface. Easy tube replacement. Easily converted on job to single, double, or four-pass tube side flow by simple change of fixed covers. Steel, shell, oversize shell connections, impingement plates and drain and vent plugs integral with shell end castings. Stainless-steel baffles assembled with steel tie rods to form protective cage for tube bundle. Removable "Karbate" tube bundle. Write for catalog sections for S-6690, S-6715 for details of applications, maintenance, sizes and characteristics of these exchangers.

Cascade coolers: For all cooling jobs involving corrosive gases and liquids. Complete cooler assembly may be made quickly from 4 standard items in 5 pipe sizes. Capacity easily enlarged or reduced by adding or subtracting standard sections. Compact construction to save plant room. No special supporting structure needed. Write for catalog section S-6780.

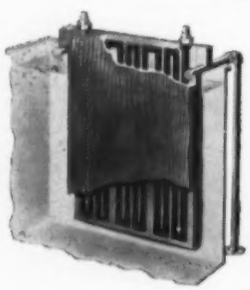
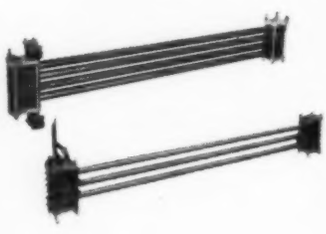


Plate heaters: Used to heat or cool corrosive liquids in tanks and vessels. Compact, completely assembled, easy to put in. Used in pickling, etching, plating and cleaning tanks. Complete size range. Models for horizontal and vertical mounting. Write for catalog section S-6620.



Concentric Tube exchangers: Available in two types. Series 10A is small, low-priced, gives true counterflow. Exceptionally good for small flow rates at narrow temperature differences . . . Series 20A manufactured with "Karbate" inner and outer piping, and is used to transfer heat between two corrosive fluids. Both have sectional construction, can be added to or subtracted from at will. Sturdy, can be moved from place to place after assembly, adapted to any method of mounting on floor, wall, or ceiling. Write for catalog section S-6670.

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

In Canada: National Carbon Limited
Montreal, Toronto, Winnipeg

A full line of "Karbate" impervious graphite pipe and fittings

for conveying corrosive chemicals includes: "Karbate" pumps of advanced design embodying impervious graphite case, impeller, and a rotary seal which eliminates the stuffing box. Pump prices reduced up to 33%. Write for catalog section S-7000 for pipe information, S-7200 for pump information.

Personnel News...

Jesse J. Booth was appointed as assistant to the general superintendent and **Frank O. Phillips** was named division superintendent of maintenance at Duquesne, Pa., works of U. S. Steel Co. A native of Shelbina, Mo., Mr. Booth attended elementary and high schools there and was graduated from the University of Missouri with an electrical engineering degree in 1910. In 1913 Mr. Booth joined United States Steel as electrical engineer at Edgar Thomson works in Braddock, Pa. He went to National Tube's Gary, Ind., plant in 1924 as assistant superintendent of the electrical department. He became superintendent of the department in 1929 and in 1935 went to Duquesne works as assistant chief maintenance engineer. In February of 1938 Mr. Booth was advanced to assistant superintendent of Duquesne's maintenance department and in November of 1943 he became superintendent of maintenance. He was named division superintendent of maintenance in January, 1948, the position he held at the time of his present appointment. Mr. Phillips was born in Valparaiso, Ind., and attended Iowa State College where he was graduated with a degree in electrical engineering in 1933. He was first employed by United States Steel as an electrician at Gary sheet and tin works in 1935. In 1937 he was transferred to Irvin works as power foreman. He went to Vandergrift works in 1940 as assistant chief electrician. Transferred to Homestead in 1941, he advanced through various positions to assistant superintendent of the 100-in. semi-continuous mill in 1949. In 1950 he became superintendent of Homestead's 45-in. mill, the position he held at the time of his present appointment.

S. D. Baumer was appointed vice president of the Airco equipment manufacturing division of Air Reduction Co., Inc. Joining the Airco general technical sales department in 1941 as steel mill specialist, Mr. Baumer was appointed assistant manager of that department in 1944 and manager in 1948. A native of Johnstown, Pa., Mr. Baumer spent a number of years in the cast iron radiator and boiler field before joining the Bethlehem Steel Co. at the Johnstown plant where he was employed in various capacities until 1941 when he joined Airco.

P. M. Fleming was appointed president of Pittsburgh Rolls division of Blaw-Knox Co., and **S. J. Moran** was named president of the Union Steel Castings division of Blaw-Knox. Mr. Fleming began work with Pittsburgh Rolls in 1913 as a timekeeper, and followed this by service in the various other departments. He was made secretary and assistant treasurer of Pittsburgh Rolls in 1917. In 1937 he became vice president in charge of sales, and in 1943 his duties were expanded to include vice president in charge of sales and operations. During the past year Mr. Fleming has been manager of the division and now assumes the divisional presidency formerly held by **Q. S. Snyder,** retired. Mr. Moran began with Union Steel Castings in 1920 as an office boy. Later becoming a clerk, then a production worker, followed by supervisory positions, he has served in virtually every job in the unit. In 1935 he was appointed plant purchasing agent, in 1937 office manager and assistant treasurer, and in 1942 production manager of the division. He was made works manager of Union Steel Castings in 1947, and during the past year has been serving at Pittsburgh Rolls as general superintendent. As divisional president, Mr. Moran succeeds **D. V. Sherlock,** who retired June 30.

Floyd C. Diaz has been appointed department superintendent of blast furnaces in the Duluth, Minn., works of American Steel & Wire Co. Mr. Diaz comes to his Duluth post from the company's Donora works in Donora, Pa., where he was general foreman of blast furnaces. He went with the wire company, a U. S. Steel subsidiary, in 1937 as a laborer.

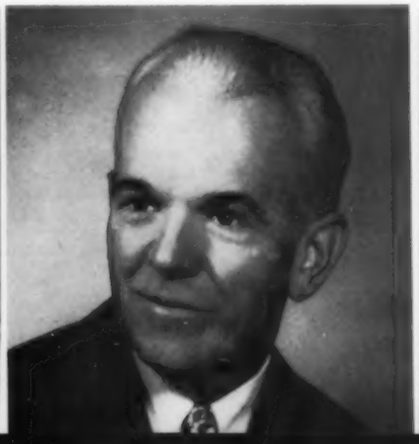
J. D. Brick has been named Pittsburgh district manager for Electric Controller and Manufacturing Co., succeeding **W. D. Falkenstein** who died June 21. Mr. Brick has been field engineer in the Pittsburgh, Pa., office of EC&M.

Frank Senior and **David Knall** announce that they have joined **Karl Juengling,** consulting engineer of Cleveland, Ohio, to form the Senior, Juengling and Knall Co. The new company will function as engineers and consultants to the iron and steel industries and will

JESSE J. BOOTH

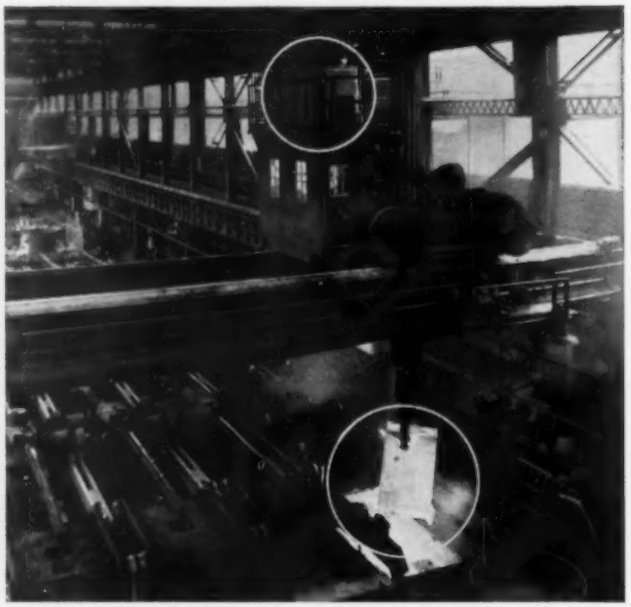
S. D. BAUMER

P. M. FLEMING



S. J. MORAN

J&L STEEL *uses...* **DRAVO CRANE CAB COOLERS** *in its "HOTTEST SPOT"*



SOAKING PIT OPERATIONS MADE MORE EFFICIENT, WORKING CONDITIONS BETTER

The hottest spot in any steel mill crane operation is over the soaking pit. Temperatures range as high as 170° F.; dirt, dust, fumes and gases limit the time any man can work his crane over this installation.

Jones & Laughlin Steel Corporation has eliminated this working hazard by installing Dravo Crane Cab Coolers on the cranes working over these hot spots.

CRANE CAB COOLERS HAVE LONG SERVICE LIFE, PROVIDE YEAR-'ROUND AIR CONDITIONING

Dravo Crane Cab Coolers are ruggedly constructed, factory assembled and pre-tested to provide years of more-than-satisfactory service. All equipment in the unit is readily accessible with ample space for quick and efficient maintenance.

In the various air conditioning functions the crane cab cooler not only filters the air, removes dust, dirt and fumes, but heats the cab in winter, cools it in summer and provides constant ventilation the year around.

AVAILABLE IN SINGLE UNIT OR IN SPLIT-TYPE UNIT; IMMEDIATE DELIVERY

Dravo Crane Cab Coolers are built in two models—the self-contained unit, mounted on any available space on the crane and the new split-type unit where the condenser section is mounted on the crane, with the conditioning section in cab.

The Dravo Crane Cab Cooler can be easily and quickly installed on any type of crane with a minimum of down-time required. Units are available now! Write for more information —or phone the nearest Dravo Office and have our representative call on you.

DRAVO **DRAVO CORPORATION**

DRAVO BUILDING, PITTSBURGH 22, PA.

PITTSBURGH • PHILADELPHIA • CLEVELAND • NEW YORK • CHICAGO
DETROIT • ATLANTA • BOSTON

have offices in the Brown-Marx Building, Birmingham, Ala. and Rockefeller Building, Cleveland, Ohio. Mr. Senior was graduated from Penn State and worked with the Bethlehem Steel Co. at Bethlehem, Pa. as assistant chief engineer prior to joining Koppers Co., Inc. of Pittsburgh, Pa. With Koppers he acted as chief engineer of the Corporacion de Fomento for the design and construction of the large integrated steel plant at Concepcion, Chile. Mr. Juengling was graduated from MIT in 1904, and engaged in engineering and construction work. In 1920 he joined the Arthur G. McKee Co. of Cleveland, Ohio as chief engineer. In 1930 Mr. Juengling left McKee and has acted as an independent consultant to the steel industry. Mr. Knall was graduated from Antioch College and worked with Inland Steel Co. in the rolling mills. He joined the H. A. Brassert Co. of New York and worked as assistant chief engineer of that company on the Chilean steel mills. He recently joined Koppers Co., Inc. and has just completed the work of construction of the new Ohio works blast furnace, and the preliminary work for the new blast furnace for Volta Redonda in Brazil.

Arch J. Cochrane has been appointed assistant manager of Chicago district operations for Youngstown Sheet and Tube Co.

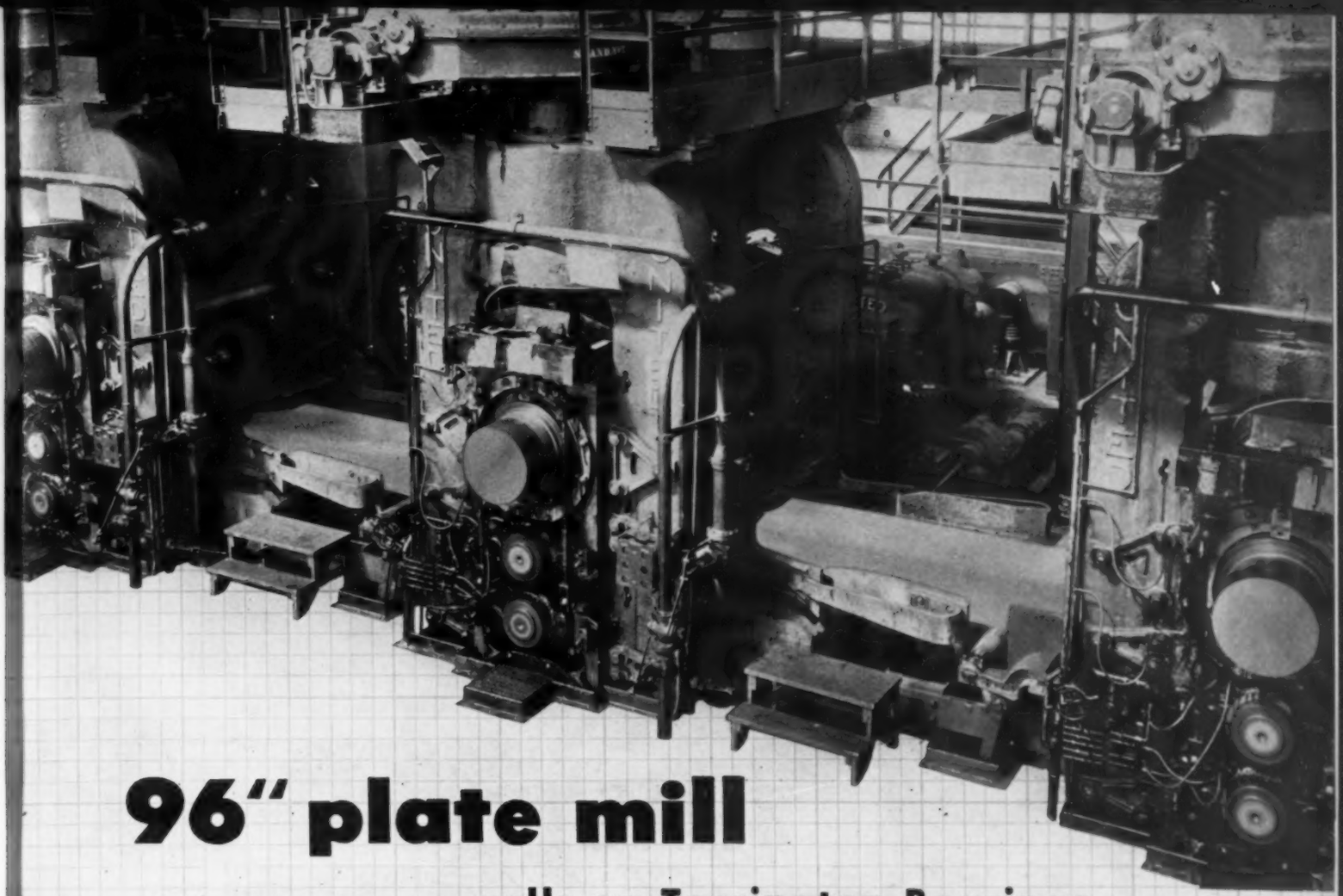
Herb Walther, Jr., development engineer for Dowell, Inc., in Tulsa, Okla., has been placed in charge of the sales of cathodic protection products for retarding electrolytic corrosion of pipe lines and industrial equipment. The new head of the cathodic protection department was formerly working with the industrial division in Richmond, Va. He will continue working in some phases of the industrial division.

H. J. Kreher was appointed assistant manager of the railroad, pig iron and chemical division, in charge of pig iron and coal chemical products, for Inland Steel Co., Chicago, Ill. Prior to his appointment with Inland, Mr. Kreher was Chicago Manager of Reilly Tar and Chemical Corp.

C. M. Maratta was named chief consulting engineer of Timken Roller Bearing Co., Canton, Ohio. Mr. Maratta went with Timken on June 4, 1917. During this time he has filled the positions of plant maintenance engineer and chief works engineer.

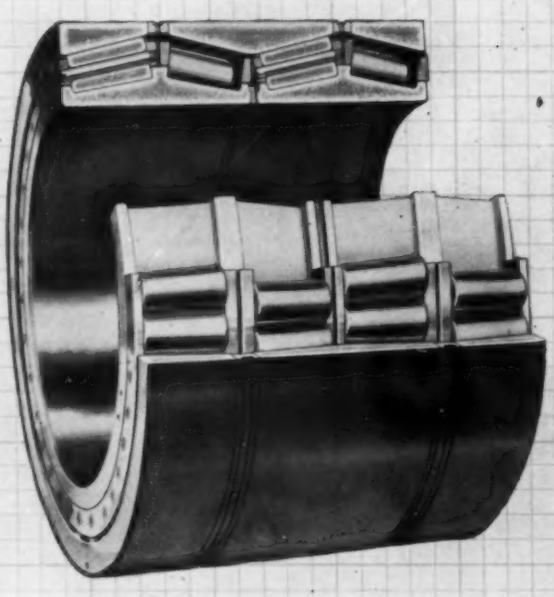
R. A. Schimpf has been promoted to chief works engineer of Timken Roller Bearing Co., Canton, Ohio. Mr. Schimpf went with Timken in 1928. In 1936 he was transferred to Columbus as assistant manager of the diesel fuel pump division and later as assistant superintendent. He was also resident engineer at the Mt. Vernon plant and utilities engineer of the Canton division before his present appointment.

Edward H. Roper was named as manager of the general technical sales department of Air Reduction Sales Co., New York, N. Y. Joining Air Reduction in 1936, Mr. Roper served in various capacities in the general technical sales department and was appointed assistant to the manager of that department in 1944. Four years later he became assistant manager of this department whose function it is to assist nation wide users of Airco products and processes in their proper applications.



96" plate mill

rolls on Torrington Bearings



Torrington Roll Neck Bearings in this 96" Plate Mill at United States Steel Company's South Works help produce high tonnages of quality steel.

Four rows of closely-spaced rollers provide high radial and thrust capacity, while the reduced cross-section of Torrington Bearings permits larger roll neck diameters for greater rigidity and strength. Torrington Bearings are manufactured by experienced craftsmen—from selected alloy steel. Special heat-treating procedures assure long service life.

Put the dependable performance of Torrington Bearings on *your* rolling mill equipment. Our engineers will be glad to help.

THE TORRINGTON COMPANY

South Bend 21, Ind. • Torrington, Conn.

District Offices and Distributors in Principal Cities of United States and Canada

TORRINGTON BEARINGS

SPHERICAL ROLLER • TAPERED ROLLER • STRAIGHT ROLLER • NEEDLE • BALL • NEEDLE ROLLERS

Edward L. Ryerson, chairman, Inland Steel Co., Chicago, Ill., was presented the Gary Memorial Medal for outstanding achievement in the iron and steel industry at the 59th General Meeting of American Iron and Steel Institute in New York, N. Y.

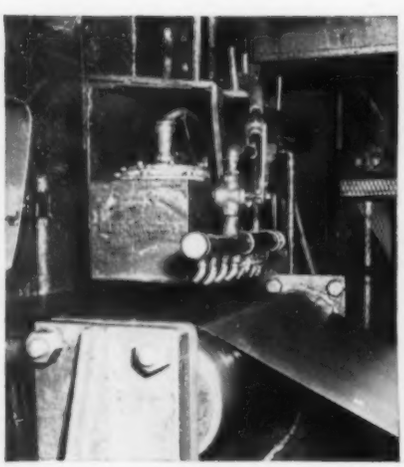
Henry W. Winkler was elected vice president in charge of research and laboratory control for Brooks Oil Co., Cleveland, Ohio, while **Joseph A. Rigby** was named vice president in charge of engineering and sales. Prior to his election as vice president, Mr. Winkler had been for eight years chief chemist of the company. A native of Oil City, Pa., and a graduate of Allegheny College, Mr. Winkler was associated for many years with Dr. P. H. Conardson who developed testing techniques for petroleum lubrication oils and greases. For 37 years he has been connected with the production of industrial lubricants, specializing in recent years in lead base lubricants. Before joining Brooks Oil he was associated with Atlantic Refining Co., Galena Oil Corp. and Valvoline Oil Co. Before being named vice president, Mr. Rigby had been manager of engineering and sales. Prior to joining Brooks Oil in 1944, he was assistant superintendent of maintenance of the Clairton, Pa., works of U. S. Steel Co.

HENRY W. WINKLER

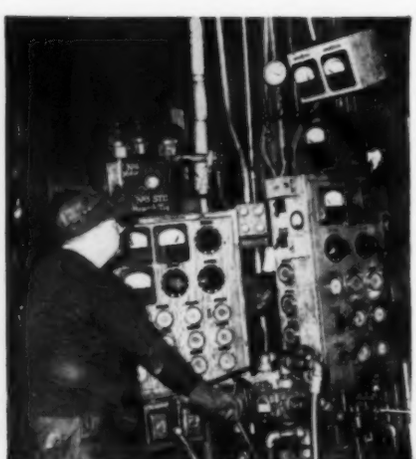
JOSEPH A. RIGBY

GE X-RAY THICKNESS GAGE helps Inland Steel

BOOST ON-GAGE TONNAGE



In a fraction of a second after strip passes the gage head, deviations, if any, show up on indicator.



Operator watches deviation indicator and makes mill adjustments when strip is off-gage.

C. R. McLeod, Asst. Supt. Cold Strip, says "Our G-E gage gives us the dependable, accurate, high-speed strip-gaging method we need. It's the best we have found for our operation."

After extensive mill modernization, speed on Inland's #5 tinplate mill was upped from 1200 fpm to 4000 fpm. This made their old gage lose accuracy and require excessive maintenance. A General Electric X-Ray Gage was then installed and has proven to be:

RUGGED — The gage operates 18 turns a week with a minimum of maintenance during rolling time.

ACCURATE — Inland now holds closer tolerances at 4000 fpm than they did with their old gage at 1200 fpm.

SIMPLE — On continuous and reversing mills, the gage can be set-up in seconds for new schedules with one simple adjustment.

For more facts call your G-E salesman or write to Sec. 687-69 for bulletins GEC-471 and GEC-485. Apparatus Dept., General Electric Company, Schenectady 5, N. Y.

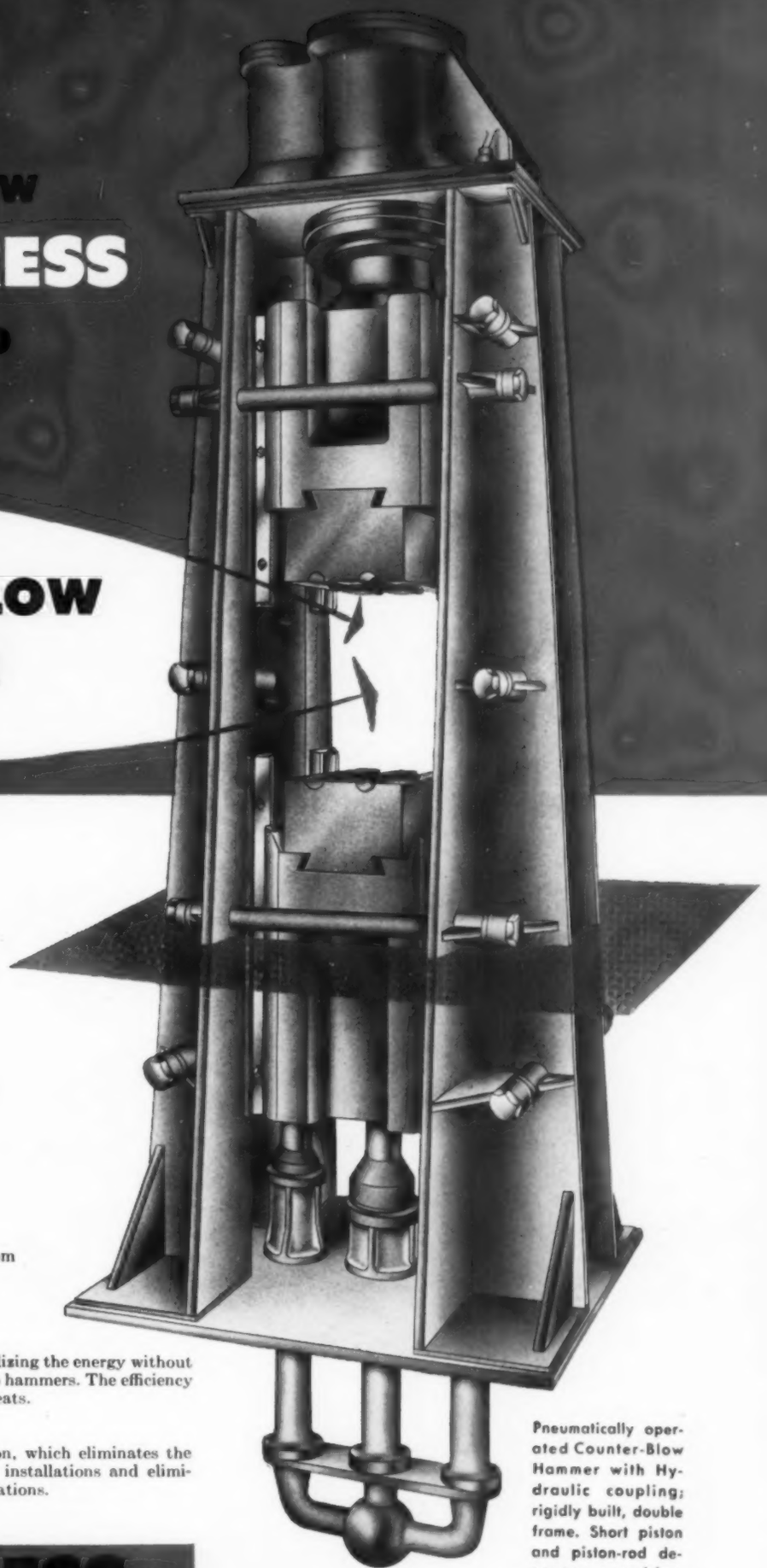
687-69

GENERAL ELECTRIC

A POWERFUL NEW HYDROPRESS PRODUCTION AID

COUNTER-BLOW HAMMER

NASMYTH'S
STEAM HAMMER
• 1843



FOR CHEAPER AND FASTER MANUFACTURE OF HEAVIER AND MORE COMPLICATED FERROUS AND NON-FERROUS FORGINGS OF HIGH METALLURGICAL QUALITIES.

- simultaneously penetrates into the part from both sides, concentrating kinetic energy and enabling formation of intricate and protruding shapes to close tolerances.

- permits shock absorption in the forging, utilizing the energy without anvil loss experienced in conventional drop hammers. The efficiency of the counter-acting strokes saves additional heats.

- does not transmit shocks to the foundation, which eliminates the destructive effect on shock-sensitive shop installations and eliminates the necessity for conventional deep foundations.

Pneumatically operated Counter-Blow Hammer with Hydraulic coupling; rigidly built, double frame. Short piston and piston-rod decrease machine height, permit exact alignment; are less subject to rupture.

HYDROPRESS INC.
ENGINEERS & CONTRACTORS

HYDRAULIC PRESSES • ACCUMULATORS • PUMPS • ROLLING MILLS • DIE CASTING MACHINES

566-568 LEXINGTON AVENUE at 51st Street **NEW YORK 22, N. Y.**

CHICAGO
DETROIT
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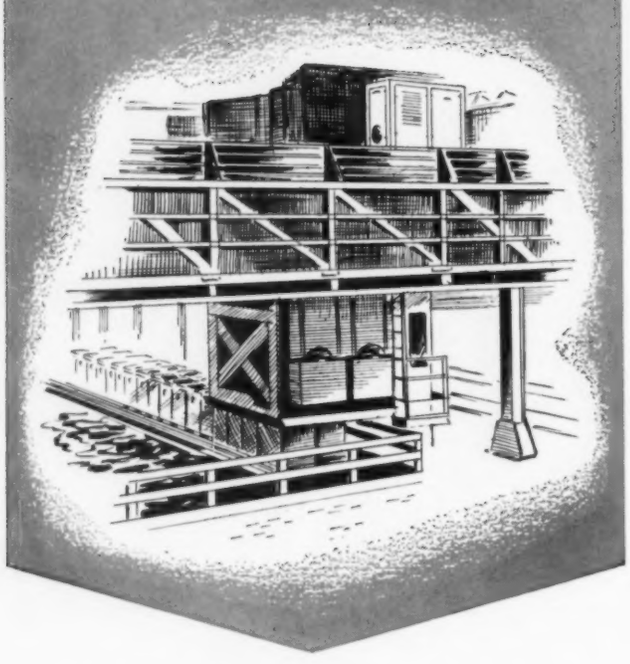
LINTERN Aire-Rectifiers
Proved On Soaking Pit Cranes
Throughout the Past Decade



It is generally agreed that the toughest crane cab to air condition is that of a soaking pit crane. The Lintern Split System is particularly effective on this type of crane since it allows the condenser unit to be located high on the trolley where it is completely protected from direct radiant heat. Inasmuch as air ducts are not required, high efficiency is maintained and installation greatly simplified.

May we send you complete information on the Lintern Aire-Rectifier and its application to your particular needs?

THE LINTERN CORPORATION
29-2 RIVERSIDE DRIVE • BEREA, OHIO

E. Milton Barber has been named executive vice president and director, Pittsburgh Steel Co., Pittsburgh, Pa. Mr. Barber was formerly president of Thomas Steel Co., Warren, Ohio, recently acquired by Pittsburgh Steel.

T. C. Finnell was appointed assistant manager of the application engineering department for the Westinghouse Electric Corp.'s motor and control division, Buffalo, N. Y. Mr. Finnell, who formerly was manager of the metallic rectifier section, succeeds **T. R. Lawson,** who has been transferred to the company's headquarters offices in Pittsburgh.

Robert M. Lundgren has been appointed vice president of Kuljian Corp., international engineering and construction firm. For the past five years, he has been closely associated with new engineering and con-

ROBERT M. LUNDGREN

struction projects. In his new capacity he will have charge of the sales program of Kuljian Corp., which maintains branch offices in five foreign countries in addition to its offices in Philadelphia and Washington.

Wilbur T. Clark has been made chief engineer of blast furnaces for Republic Steel Corp., Cleveland, Ohio. A graduate of Purdue University, Mr. Clark has been with Republic 15 years as a designer, chief draftsman and assistant chief engineer at the Cleveland district.

Roy W. Kroeger succeeds W. T. Clark as assistant chief engineer for Republic Steel Corp.'s Cleveland district.

Frank N. Nolan has been made superintendent of the mechanical department, Republic Steel Corp., Buffalo, N. Y. Mr. Nolan started with Buffalo in 1927 as an electrician. He was made electrical foreman in 1933 and general foreman of maintenance and electrical in 1949.

Walter L. Radley has been appointed superintendent of combustion engineering at Republic Steel Corp., Buffalo, N. Y.

Edward O. Barkley has been named assistant superintendent of the mechanical department at Republic Steel Corp., Buffalo, N. Y.

Frank X. Sieloff was named sales manager of Elco Lubricant Corp., Cleveland, Ohio. Mr. Sieloff has been a sales engineer with Elco since 1949.

Here's How to Erase Smoke Troubles

VIOLATION OF SMOKE ORDINANCE

LOSS OF FUEL ECONOMY

BAD COMMUNITY RELATIONS

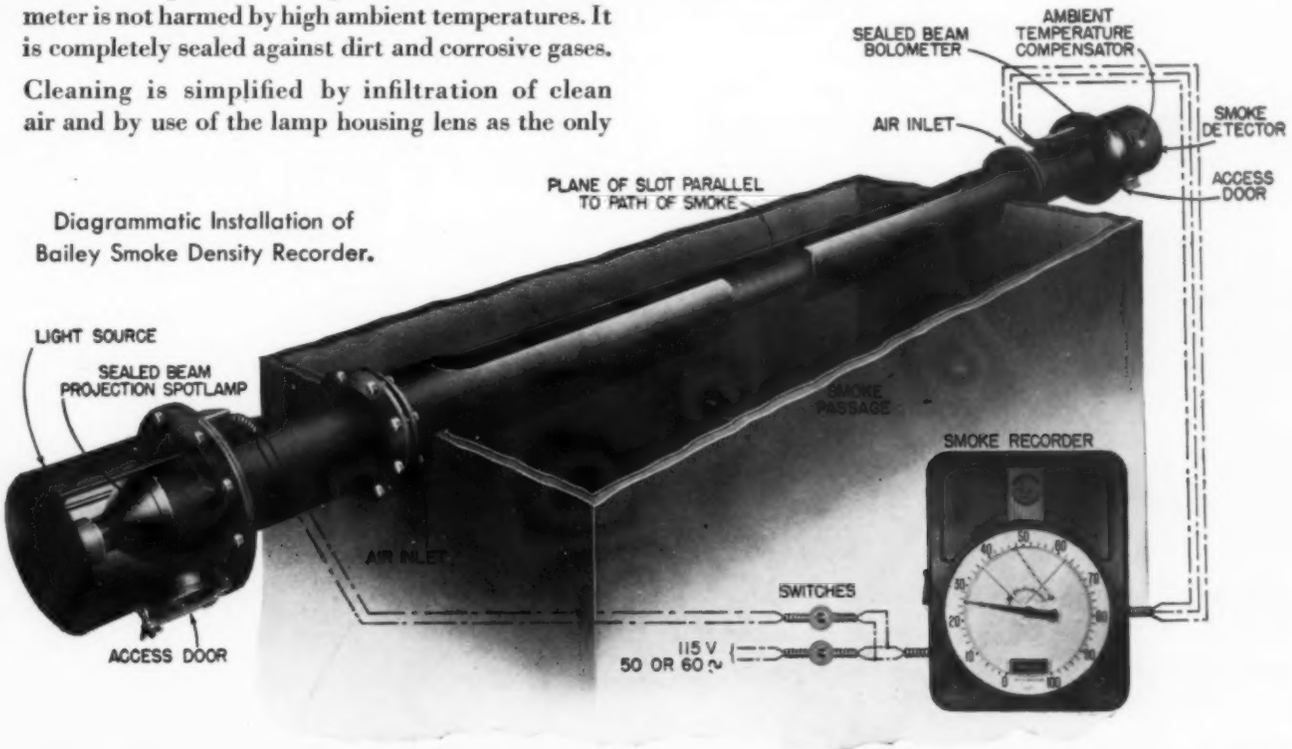
★ One of your first steps in erasing these troubles which result from excessive smoke, should be the installation of a Bailey Smoke Density Recorder. This 24-hour recorder is not an ordinary photo-cell instrument. Instead it detects smoke density by a Bolometer which is simply a sturdy tungsten filament and a parabolic mirror, mounted in a standard sealed beam automobile head lamp housing.

In using this simple, unique smoke detector, you do not have to provide cooling devices since the Bolometer is not harmed by high ambient temperatures. It is completely sealed against dirt and corrosive gases.

Cleaning is simplified by infiltration of clean air and by use of the lamp housing lens as the only window between the Bolometer and the gas passage.

It's easy to secure and maintain alignment of the sealed beam light source with the Bolometer since they are mounted at opposite ends of a slotted pipe which extends across the smoke passage.

For complete information on how you can profitably use this unique instrument to erase your smoke troubles, ask for Bulletin 211, "Bailey Smoke Density Recorder".



Diagrammatic Installation of Bailey Smoke Density Recorder.

G-29

BAILEY METER COMPANY

1047 IVANHOE ROAD, CLEVELAND 10, OHIO • BRANCH OFFICES IN PRINCIPAL CITIES

BAILEY METER COMPANY LIMITED, MONTREAL, CANADA

Let Bailey Smoke Density Recorders Watch Your Stacks

All at one time . . .
it removes rust,
removes oil,
prepares the metal
for painting

This FREE Folder Tells About Oakite's Great New Pre-Paint Cleaner

OAKITE Compound No. 33 is a cleaning-phosphating material that simultaneously removes oil and rust and conditions the metal surface for painting.

It also removes heat scale and other oxides, carbon smut, soldering and welding residues, identification inks and other soils from steel, cast iron, aluminum sheet and castings.

Oakite Compound No. 33 is a great soak cleaner for metal parts of moderate size; and great for hand-swabbing on large pieces like cabinets, desks, doors and truck cabs.

Oakite Compound No. 33 saves money; *frequently eliminates pickling operations on moderately rusty steel.*

FREE Write to Oakite Products, Inc., 28A Thames St., New York 6, N. Y., for your copy of Folder F7993 on "*Oakite Compound No. 33*".

SPECIALIZED INDUSTRIAL CLEANING
OAKITE
MATERIALS • METHODS • SERVICE
Technical Service Representatives in Principal Cities of U. S. & Canada

Dr. George J. Goepfert was named director of research for both Speer Carbon Co. and International Graphite and Electrode Corp., St. Marys, Pa. Prior to his present appointment, Dr. Goepfert was supervising engineer of the organic chemical laboratory of the research and development division of the Carborundum Co., Niagara Falls, N. Y.

A. F. Hills, in a recent reorganization, has been elected president of Crouse-Hinds Co., Syracuse, N. Y. **W. L. Hinds** continues as chairman of the board. **W. C. Blanding** was named executive vice president, **J. R. Tuttle** became vice president and treasurer, **C. M. Crofoot** was named honorary commercial vice president and **E. R. Monesmith** was appointed vice president and general sales manager. The following other changes were also announced: **F. W. Clary,** vice president—publicity and public relations; **C. H. Bissell,** vice president-engineering; **J. G. Hummel,** vice president and general manager—manufacturing; **Hamilton Armstrong,** vice president—plant operations; **R. J. Sloan,** secretary; **W. F. Beach,** controller; and **R. J. Jones,** assistant to vice president—office manager. New commercial vice presidents are **R. P. Northup, A. H. Clarke, F. J. Fancher,** and **K. W. Mackall.**

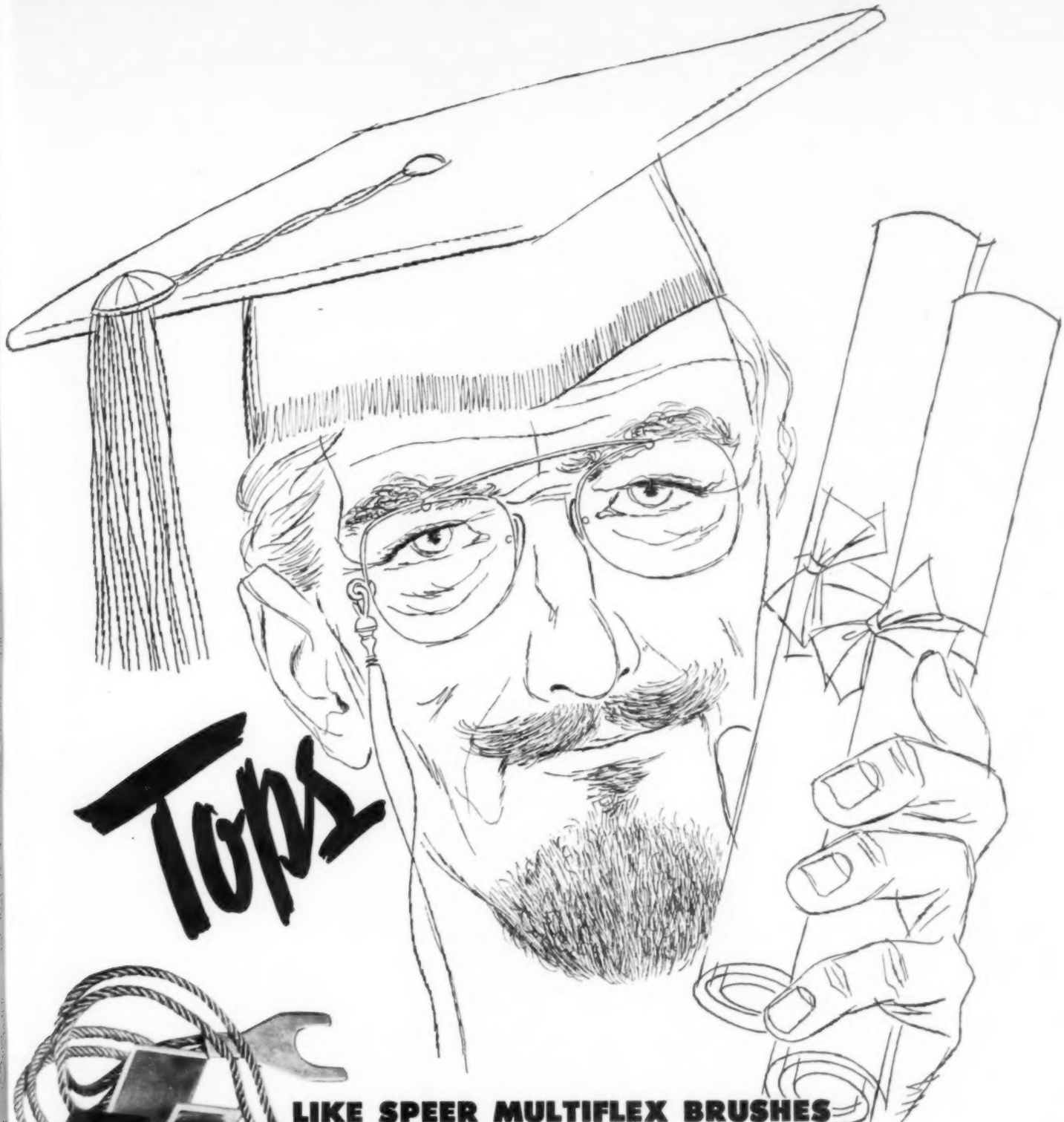
Crawford B. Murton, for the last 27 years works manager of the Inland Steel Co., Chicago Heights, Ill., plant, will retire August 1 after 48 years with the company. **William Porter Goodman,** general superintendent of the Chicago Heights plant since 1946, will succeed Mr. Murton as chief operating official without change in title. Mr. Murton is the son of one of the first rollers and mill superintendents of the Indiana Harbor works, Robert Crawford. A brother, Arthur Edward Murton, who also followed his father's profession, is a vice president of Continental Foundry and Machine Co.

D. L. McBride, formerly superintendent of open hearths, Bethlehem Steel Co., Johnstown, Pa., is now with the Metallurgical Advisory Board of the National Research Council, Washington, D. C.

L. A. Holder was appointed chief mechanical engineer of Timken Roller Bearing Co., Canton, Ohio. Mr. Holder received his education at Cleveland School of Technology and has been with Timken since 1928.

H. J. Urbach was named executive engineer of Timken Roller Bearing Co., Canton, Ohio. Since 1933, Mr. Urbach has served with the railroad engineering division and the diesel pump division as service engineer. In 1946 he was appointed works engineer for the company.

Thomas G. Simison was appointed today to the position of division superintendent of rolling mills connected with the making of tin-plate and flat rolled products at Kaiser Steel Corp., Fontana, Calif. Mr. Simison, a resident of Ontario, has been with the company since October 1948 and was formerly assistant superintendent in the merchant mill. Continuing as division superintendent of rolling mills is **Robert C. Madden,** who will be responsible for the operation and production of all mills rolling structural, merchant and tubular products.



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SPEER Carbon CO.

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Subsidiaries

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Jeffers Electronics, Inc.

7586

David P. Williams, a representative in the Pittsburgh, Pa., sales district of Heppenstall Co., has been awarded its president's trophy as "salesman of the year." Mr. Williams joined the Heppenstall Co. in 1947. He was formerly vice president of the Vulcan Mold and Iron Co., Latrobe, Pa.

Norman R. Amberg was appointed assistant works manager, and **Harvey W. Wesenberg,** supervisor of materials handling for the Philadelphia, Pa., division of Yale and Towne Manufacturing Co.

Daniel S. Wilkin has been appointed director of personnel of Reserve Mining Co. Reserve Mining Co. is owned by Armco Steel Corp., Republic Steel Corp. and National Steel Corp. It is developing a process to extract iron minerals from taconite rock. Succeeding Mr. Wilkin, who has been employment advisor at Armco, will be **Rowan F. Crawford.**

Lloyd F. Giegel was named branch manager of the Gary, Ind., sales office of the Reliance Electric & Engineering Co. **Daniel J. Donnelly** was appointed in a sales engineering capacity to the company's Philadelphia, Pa., office.

Thomas E. Akers was elected president, and **Maurice N. Trainer** was elected chairman of the board of Dominion Brake Shoe Co., Ltd. **Kenneth T. Fawcett** was appointed vice president of the American Brakeblok and Kellogg divisions of the company.

George A. Bulmer has been given the position of manager of the newly formed west coast branch of the Insul-Mastic Corp. of America, Pittsburgh, Pa. Mr. Bulmer's headquarters will be in Los Angeles, Calif.

Gibson E. Brock has been named assistant resident engineer of the design engineering department at Aliquippa, Pa., works of Jones and Laughlin Steel Corp.

Samuel C. Faddis was appointed chief metallurgist, Pittsburgh, Pa., works of Jones and Laughlin Steel Corp. **Si Feigenbaum** was named assistant chief metallurgist, Pittsburgh works.

Dale B. Kennedy was appointed general plant foreman at the Electricweld Tube division of Jones and Laughlin Steel Corp. in Oil City, Pa. He succeeds J. C. Lehner who resigned recently. **J. W. Culver,** formerly assistant plant metallurgist and inspector, succeeds Mr. Kennedy as plant metallurgist and chief inspector.

Orville L. Longbrake has been appointed defense regulation engineer for the American Steel & Wire Co., Cleveland, Ohio. In his new post in the general engineering department Mr. Longbrake will analyze and interpret government orders and regulations affecting engineering and maintenance operations in the wire company's 14 plants located in nine cities.

Avery C. Newton has been appointed executive secretary of the Refractories Institute. The Refractories

A COMPLETE *Steel Mill* Engineering Service

The photograph at the right is a partial view of the new and enlarged York offices and drafting room at 951 Penn Avenue, Pittsburgh, where we have facilities for a complete engineering and construction service for steel mills. This includes the design of buildings, foundations, and equipment, as well as project planning, coordination, and cost control. Write for information about our services.

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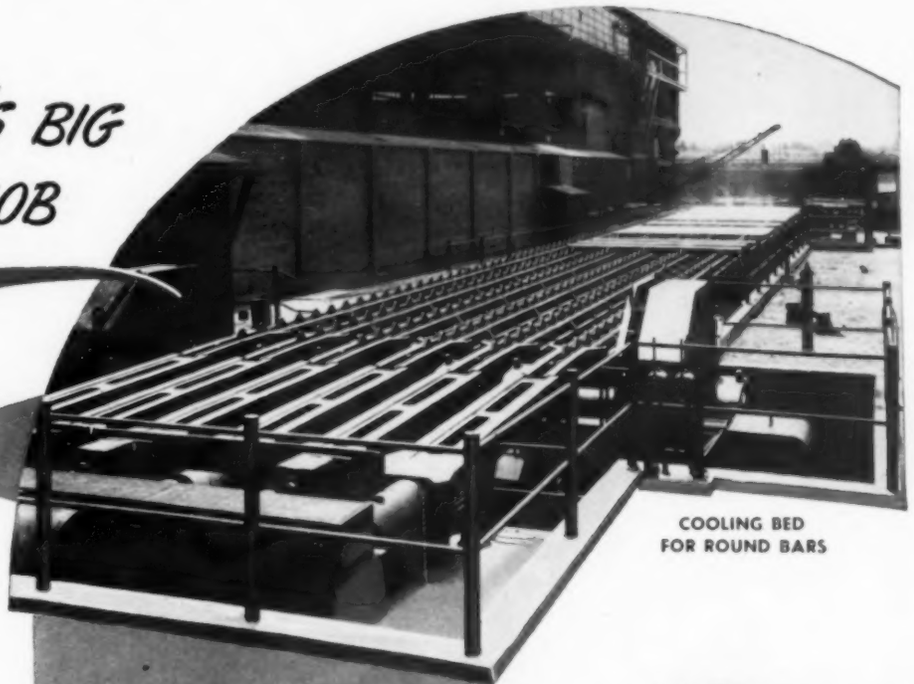

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FOR ROUND BARS

F&Y Products

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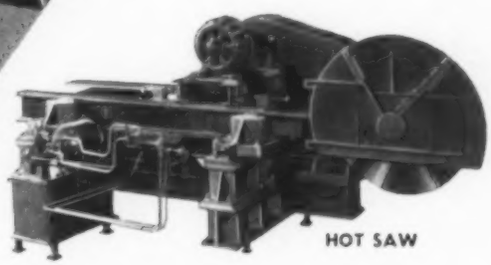
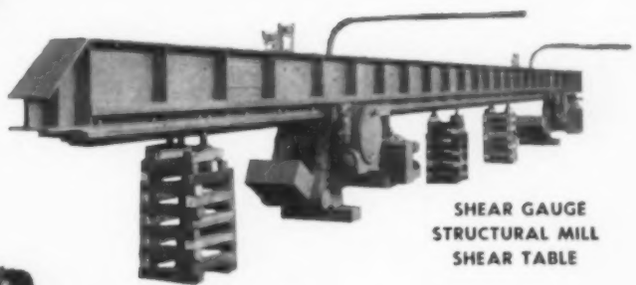
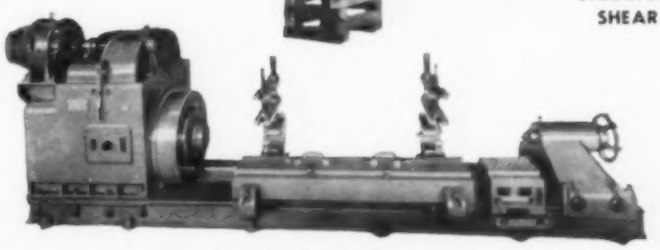
- HYDRAULIC SLAB AND BILLET PILERS
- STRIP AND SHEET OILING EQUIPMENT
- SHEET SCRUBBER AND CLEANING LINES
- HOT SAWS—ROCKING AND SLIDE TYPES
- HOT BEDS—COOLING BEDS—TRANSFERS
- BILLET EJECTORS—PINCH ROLL STANDS
- SLITTERS—SPECIAL SHEARS AND GAUGES
- TILTING TABLES—TRAVELING AND LIFTING TABLES
- CONTINUOUS PICKLING LINES—ROLLER LEVELLERS
- FURNACE CHARGING EQUIPMENT—FURNACE PUSHERS
- STRIP STEEL COILERS AND REELS—SCRAP BALLERS
- RAILROAD SPIKE FORMING MACHINES—ROLL LATHES
- SHEET GALVANIZING LINES—WIRE PATENTING FRAMES
- STRETCHER LEVELLERS—ANGLE AND SHAPE STRAIGHTENERS
- ROLLING MILL TABLES—GEAR AND INDIVIDUAL MOTOR TYPES
- DUCTILE CASTINGS (80,000 PSI)
- MACHINERY BUILT TO CUSTOMER'S DESIGN AND DETAIL DRAWINGS



HOT SAW



SHEAR GAUGE
STRUCTURAL MILL
SHEAR TABLE



42" ROLL LATHE

The Youngstown Foundry & Machine Co.

OVER SIXTY YEARS OF SERVICE TO THE STEEL INDUSTRY

Youngstown, Ohio

Institute was recently incorporated as a non-profit association for the improvement and advancement of industrial trade and consumer relations among the manufacturers of refractories products. National headquarters are located in the First National Bank Building, Pittsburgh, Pa.

I. Melville Stein has been elected to the newly created post of executive vice president of Leeds & Northrup Co., Philadelphia, Pa. Mr. Stein has been a vice president, and is director of research.

Chester H. Lang, vice president of the General Electric Co., Schenectady, N. Y., for the past 10 years, has been appointed to a new post in charge of public relations. Mr. Lang's office will be at the company's executive offices in New York, N. Y.

Stephen P. Curtis, chief construction engineer, construction engineering bureau, manufacturing division, United States Steel Co., has been assigned as project construction manager in charge of the construction of Fairless works near Morrisville, Pa. In his new capacity Mr. Curtis will supervise and coordinate the construction, now under way at Morrisville, of the Fairless works' facilities of both United States Steel Co. and the National Tube Co., United States Steel Corp. subsidiaries.

James P. Stewart has been elected president of De Laval Steam Turbine Co., Trenton, N. J. Mr. Stewart previously served in the capacity of executive vice president. **Wencel A. Neumann, Jr.** has been elected vice president of industrial sales. **H. G. Bauer** has been elected vice president of engineering and will also continue as manager of marine sales. He was previously vice president and executive engineer. **Charles A. Jurgensen** has been elected vice president of manufacturing. He will continue to serve as works manager.

Lawrence L. Garber, general manager, American-Fort Pitt Spring division, H. K. Porter Co., Inc., Pittsburgh, Pa., has been elected a vice president of the H. K. Porter Co.

Stevens H. Hammond was elected chairman of the board of Whiting Corp., Harvey, Ill. **J. A. Handley** will continue as vice president and chief executive officer.

C. R. Horton, Jr. was appointed manager of the engineering development department of Dravo Corp.'s engineering works division, Pittsburgh, Pa. Mr. Horton has been with Dravo in various engineering and production capacities since he was graduated from Massachusetts Institute of Technology in 1936.

J. D. Streett, vice president in charge of development of Granite City Steel Co., Granite City, Ill., has been elected president and treasurer of the Laclede-Christy Co. Mr. Streett will take over the new position immediately, succeeding **D. N. Watkins,** president and general manager, whose resignation has been accepted. **A. B. Agnew** was elected president of the Laclede-

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...and in the BEST quality*

COPPER

Valve Seats
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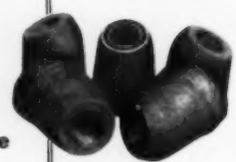
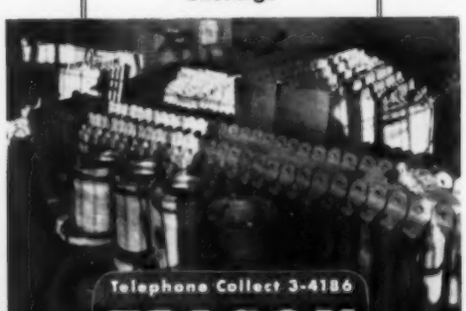


Copper and Bronze Castings



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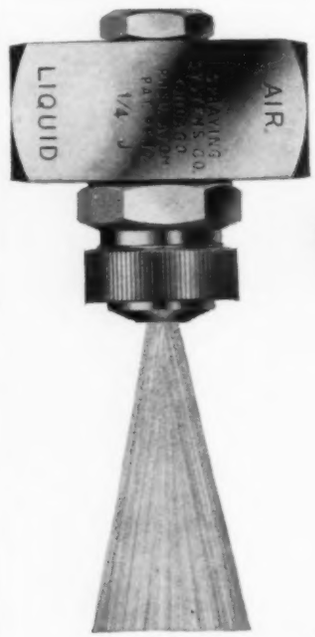
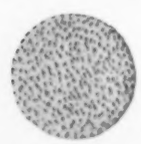
YOUNGSTOWN 3, OHIO
Established 1890 – Incorporated 1895

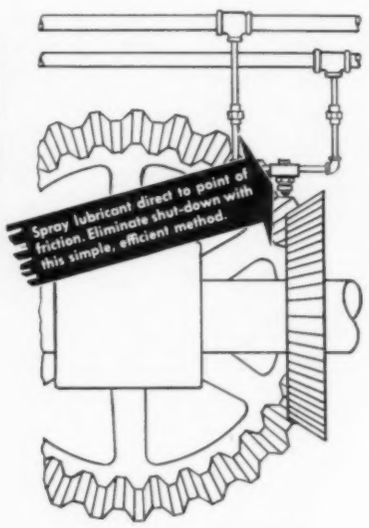
LICENSED MAKERS OF ALL PATENTED DESIGNS

*DEPENDABLE FOR 61 YEARS, SINCE 1890





Write for Data Sheet 4516 and complete information on Spraying Systems Spray Nozzles for steel mill application.



direct-to-gear lubrication with SPRAY NOZZLES

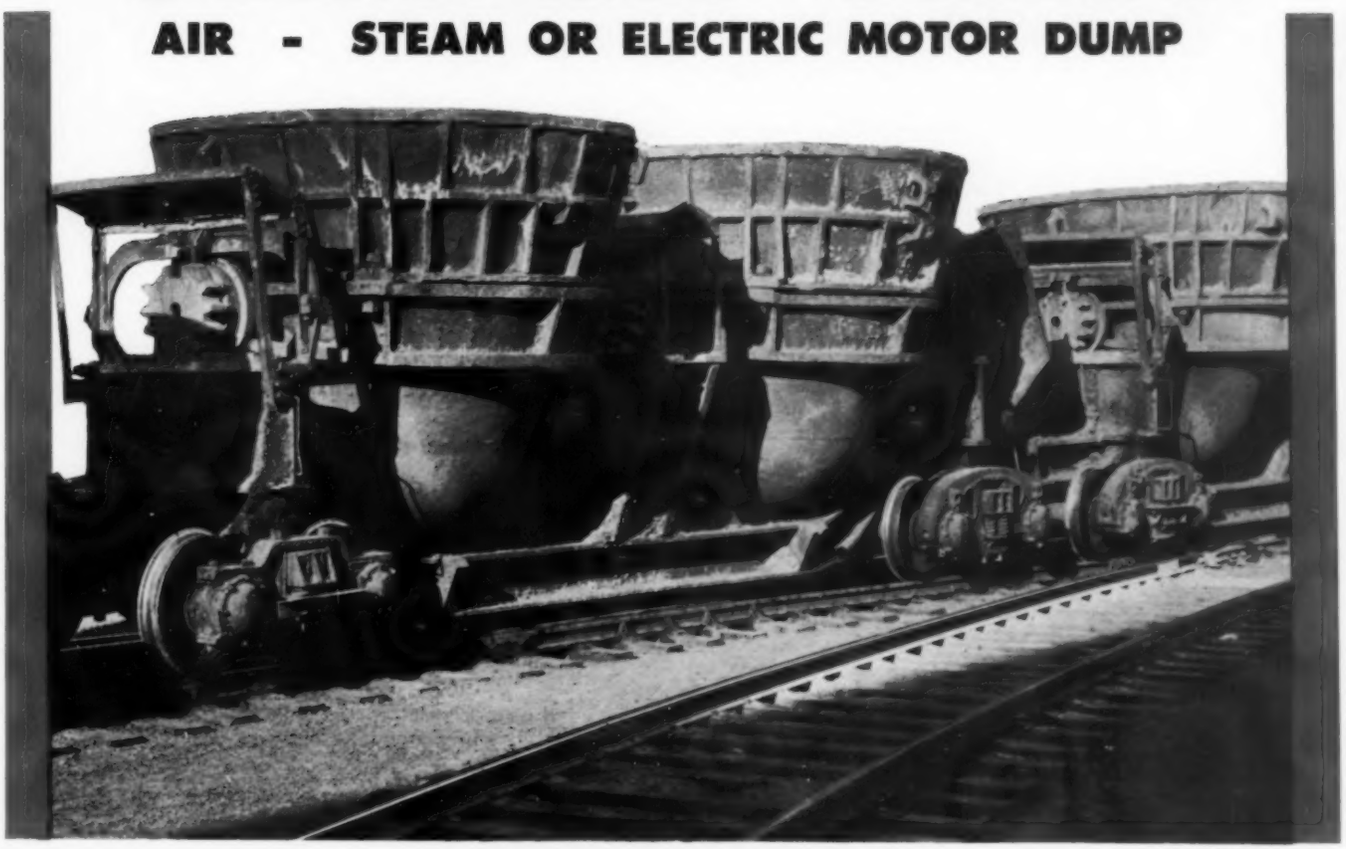
Spraying Systems Pneumatic Atomizing Nozzles provide efficient, low cost lubrication for gears or other moving parts. Lubricant materials from very light oils to greases may be successfully sprayed. Advantages of this method are that lubricant is applied where required without need of shut-down . . . and the system does not have to be an in-built part of the machine.

SPRAYING SYSTEMS CO. 3262 RANDOLPH STREET BELLWOOD, ILLINOIS
(Suburb of Chicago)

TREADWELL

CINDER CARS

AIR - STEAM OR ELECTRIC MOTOR DUMP



800 CUBIC FOOT TWIN POT CAR

Increased Blast Furnace Capacity

REQUIRES

Additional Cinder Handling Equipment

TWIN POT CARS will enable you to HANDLE 20% MORE SLAG on the same track length

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Christy Co. of Pennsylvania, a subsidiary, and will also serve as vice president in charge of operations and as a director of the parent company.

Douglas J. Donohue has been appointed Atlantic district Sales manager for Trumbull Electric, department of General Electric Co., Plainville, Conn. Mr. Donohue will maintain his office in Philadelphia, Pa.

W. H. Dupka has retired as a vice president and director, and a member of the executive committee of the Jones & Laughlin Steel Corp., Pittsburgh, Pa.

D. V. Sherlock, a director and vice president of Blaw-Knox Co., and president of Union Steel Castings division, has announced retirement from active management duties, effective June 30. Mr. Sherlock will continue as a director of Blaw-Knox Co.

Obituaries

William D. Falkenstein, 56, Pittsburgh district manager of Electric Controller & Mfg. Co. died suddenly June 21. Mr. Falkenstein had been in the EC&M Pittsburgh office since World War I.

Edward L. Clair, 57, president of the Interlake Iron Corp. with plants in Toledo, Chicago, Duluth and Erie, Pa., died June 13.

John M. Hopwood, 67, chairman of the board of the Hagan Corp. and its subsidiaries, died June 8, after a lengthy illness. Death occurred in Vero Beach, Fla., where he had been at his winter home for several months.

Frank S. Schuyler, 66, retired manager of Allis-Chalmers Detroit, Mich., district office, died June 10 following a brief illness. Mr. Schuyler completed 30 years as manager of the Company's Detroit district before retiring on December 31, 1950 after 43 years of continuous service with Allis-Chalmers.

J. Gordon Gage, 64, manager of the Butler, Pa., division of Armco Steel Corp., died June 16 while playing golf at Cambridge Springs, Pa. Mr. Gage was born in 1887 in Florence, Ontario, Canada. He joined Armco at Middletown, Ohio, in 1910 as an electrician, became electric power foreman in 1912, and assistant superintendent of the electric department later that year. He was advanced to chief electrician in 1916 and was transferred to the Butler, Pa., division of Armco in 1929 as superintendent of maintenance. In 1931 he was given the added responsibilities of chief engineer, and in 1933 he was appointed general superintendent. He became manager of the division in 1945.

Eugene J. McCleary, 61, manager, blast furnace division, Great Lakes Steel Corp., Ecorse, Mich., for 21 years, died May 20.

Browning Mill Type Cranes
have **PLENTY OF STRENGTH**
where strength is needed!

Satisfying A.I.S.E. specifications, Browning Mill Type Cranes incorporate types of motors and controls on which you have standardized. This flexibility suits your VRB crane *perfectly* to your needs. Our design, springing from 50 years' experience, places plenty of strength where it is required.

"Built as you yourself would build them"

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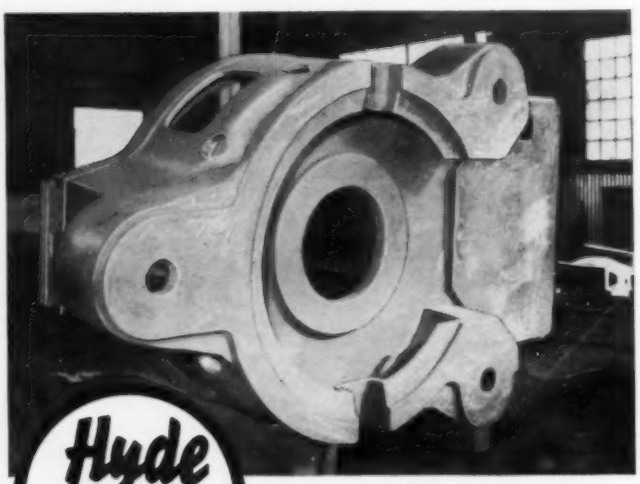
VICTOR R. BROWNING & COMPANY, Inc.
BOX 309, WILLOUGHBY (CLEVELAND), OHIO
Designers and Builders of Electric Overhead Traveling Cranes and Hoists and Electric Revolving Cranes



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SEMI-STEEL and GRAY - IRON

Castings up to 80,000 pounds — Furnace Castings, Machinery Castings, Slag Pots, Bases, Lathes, Heavy Tools, Housings, etc.

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Design Engineer
Construction Engineering Bureau
United States Steel Co.
Pittsburgh, Pa.

SHUNZO ASAMURA
Chief Engineer of Plant Engineering
Yawata Iron and Steel Works
Yawata, Japan

MARION G. CROSTHWAIT
Superintendent
Fairfield Wire Works
Tennessee Coal, Iron & Railroad Co.
Birmingham, Ala.

IRWIN C. CROSS
Roller 29 In. Mill
Kaiser Steel Corp.
Fontana, Calif.

BURNIS CUMMINGS
Assistant Superintendent
M&E Department
Tennessee Coal, Iron & Railroad Co.
Bessemer, Ala.

STEPHEN R. CURTIS
Chief Construction Engineer
Construction Engineering Bureau
United States Steel Co.
Pittsburgh, Pa.

E. A. DELARUE
Engineer
S.E.C.I.M.
Paris, France

R. C. EHRHARDT
Designer
Design Engineering Department
Jones & Laughlin Steel Corp.
Aliquippa, Pa.

J. W. FERGUSON
Assistant Superintendent Roll Shop
Kaiser Steel Corp.
Fontana, Calif.

MERLE L. GRUVER
Superintendent of Maintenance
Midvale Co.
Philadelphia, Pa.

HENRY B. HARRIS
Development Engineer
Inland Steel Co.
East Chicago, Ind.

JOHN HERTZA
Maintenance Foreman
Ford Motor Co.
Dearborn, Mich.

WILLIAM P. HOFFMAN
Assistant Superintendent Maintenance
Wisconsin Steel Works
International Harvester Co.
Chicago, Ill.

ROBERT A. HOGUE
Senior Engineer
Inland Steel Co.
East Chicago, Ind.

JOHN M. HOLLIS
General Electrical Foreman
44—46—76 In. Mills
Inland Steel Co.
East Chicago, Ind.

MELVIN S. HOUGH
Lubrication Engineer
United States Steel Co.
Clairton, Pa.

JAMES M. HOWARD
Design Engineer
Inland Steel Co.
East Chicago, Ind.

CARTHELEDGE L. HUEY, JR.
Practiceman
M & E Department (Wire Works)
Tennessee Coal, Iron & Railroad Co.
Fairfield, Ala.

WILLIAM P. JENKINS
Superintendent
S. W. Field Maintenance
United States Steel Co.
Clairton, Pa.

HARRY L. JENTER
Chief Engineer
American Steel & Wire Co.
Cleveland, Ohio

BENNIE RAYMOND JOHNSON
Engineer
Atlantic Steel Co.
Atlanta, Ga.

CHARLES F. KIRKLAND
Senior Engineer
Inland Steel Co.
East Chicago, Ind.

ANTHONY C. KRISCHUNAS
Squad Leader
Chicago District
Republic Steel Corp.
Chicago, Ill.

EDWARD A. LAINE
Plant Engineer
Allegheny Ludlum Steel Corp.
West Leechburg, Pa.

JOHN M. LIEBER
Foreman — Rolling Mill
John A. Roebling's Sons Co.
Trenton, N. J.

WILLIAM A. MILLER
Superintendent Rolling Mills
John A. Roebling's Sons Co.
Trenton, N. J.

JOHN B. MITCHELL, JR.
Assistant Turn Foreman
Hot Strip Mill
Youngstown Sheet & Tube Co.
Youngstown, Ohio

JOHN OANCEA
Design Draftsman (Electrical)
Homestead Steel Works
United States Steel Co.
Munhall, Pa.

CARL A. OGREN
Foreman, Roll Shop
Kaiser Steel Corp.
Fontana, Calif.

RAY OWENS
Chief Pyrometrist
Tennessee Coal, Iron & Railroad Co.
Birmingham, Ala.

RALPH G. PRESTON
Assistant to Manager
Plant and Production Engineering
Ford Motor Co.
Dearborn, Mich.

Associate

RICHARD L. BERRY
Sales Engineer
American Brakeblok Division
American Brake Shoe Co.
Chicago, Ill.

C. E. BISHOP
Junior Engineer
Engineering Department
Reynolds Alloys Co.
Listerhill, Ala.

E. C. BREKELBAUM
Vice President in Charge of Engineering
Harnischfeger Corp.
Milwaukee, Wis.

J. D. CASHMAN
Sales Engineer
Detroit Ball Bearing Co.
Detroit, Mich.

ROBERT J. CROSS
Industrial Sales Representative
Socony-Vacuum Oil Co., Inc.
Detroit, Mich.

CARL W. EK
Sales Engineer
Westinghouse Electric Corp.
Chicago, Ill.

R. D. FAYTINGER
Control Specialist
General Electric Co.
Pittsburgh, Pa.

JEROME D. FEATHERMAN
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United States Tube & Foundry Co.
Brooklyn, N. Y.

G. W. FLYNN
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Lintern Corp.
Berea, Ohio

H. D. GLENDENNING
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General Engineering Department
Northern Aluminum Co., Ltd.
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ANGUS D. HENDERSON
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WILLIAM O. McKELVEY
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Bowser, Inc.
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American Brake Shoe Co.
New York, N. Y.

D. W. NEVILLE
Vice President
F. H. McGraw & Co.
Chicago, Ill.

IRVING H. PEAK
Field Engineer
Electric Controller & Mfg. Co.
Ardmore, Pa.

W. K. RIEMENSCHNEIDER
General Superintendent
Union Metal Manufacturing Co.
Canton, Ohio

GLENN R. SMITH
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Electric Service Manufacturing Co.
Philadelphia, Pa.

L. J. SUELZER
District Manager
Bowser, Inc.
Pittsburgh, Pa.

NEWTON NICHOLS TEICHMANN
Engineer
Lewis Foundry & Machine Division
Blaw-Knox Co.
Groveton, Pa.

JOHN E. TWILLEY
Branch Manager
Moffatt Bearings Co.
Baltimore, Md.

J. WALTER WALLACE
Sales Representative
National Bearing Division
American Brake Shoe Co.
Meadville, Pa.

HOWARD H. WILDER
Manager Iron Foundry Division
Vanadium Corp. of America
Detroit, Mich.

WILLIAM A. YOCHUM
Sales Engineer
Manning, Maxwell & Moore, Inc.
Detroit, Mich.

ALBERT M. ZAHN
Looper
Bethlehem Steel Co.
Sparrows Point, Md.

RICHARD J. YURKANIN
Youngstown Manager
Clark Controller Co.
Youngstown, Ohio

Junior

JOHN R. BARON
Foreman Trainee — Crane Repair
Gary Sheet & Tin Mill
United States Steel Co.
Gary, Ind.

WILLIAM W. CLARKE
Engineer (Trainee)
Inland Steel Co.
East Chicago, Ind.

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40″ BLOOMING MILL TABLES AND MANIPULATOR

Shop view of 40″ Blooming Mill Manipulator and Mill Tables, furnished with a Morgan 40″ Blooming Mill, having Twin Motor Drive. Manipulator is of the overhead type, electrically driven with retractable heads so the table rollers can be removed without dismantling the manipulator heads.

Table girders are of cast steel box section type with integral oil trough on drive side. All gears are totally enclosed, operating in oil, and have hardened teeth. All bearings are of anti-friction type, lubricated through a centralized motor operated system.

Your inquiries appreciated.

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DESIGNERS • MANUFACTURERS • CONTRACTORS • BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS • ELECTRIC TRAVELING CRANES • CHARGING MACHINES • INGOT STRIPPING MACHINES • SOAKING PIT CRANES • ELECTRIC WELDED FABRICATION • LADLE CRANES • STEAM HAMMERS • STEAM HYDRAULIC FORGING PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

Equipment News...

ALL-PURPOSE MILL

▲ To meet the need of many manufacturers for a small, compact, inexpensive and versatile all-purpose mill for the cold rolling of narrow, thin strip, United Engineering and Foundry Co. has developed a new, completely integrated "Package Mill."

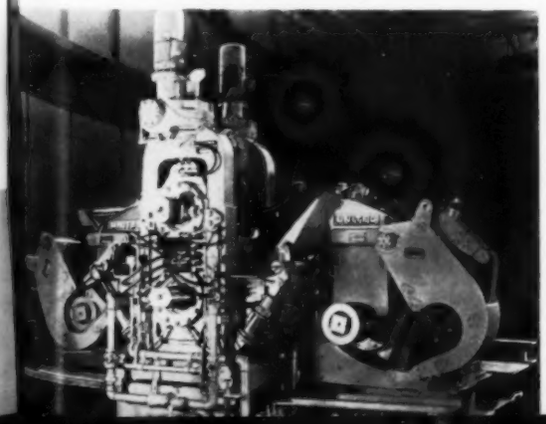
Each unit is furnished fully equipped with roller bearing mounted rolls, recirculating coolant system, mill guides, tension reels, belt wrappers if desired, strippers and drives all mounted on a fabricated base which also serves as a rolling coolant reservoir and lubricant reservoir. No cellars or elaborate foundations are needed for its installation. All drive motors are also mounted on the single fabricated base.

The "Package Mill" comes in three sizes — 2½ in. and 10 in. × 10 in., 3 in. and 16 in. × 16 in. and 4½ in. and 22 in. × 22 in. It is designed to roll copper, brass, aluminum, low carbon, high carbon and stainless alloy steels at speeds of 500 to 2000 fpm, starting with thicknesses of .030 in. to .050 in. and finishing to .002 in. to .004 in.

The mill can be furnished either for one way rolling or for reversing service. It can be equipped with motorized or hand screwdowns, either with sleeve type or collapsing mandrels. The collapsing mandrels can be with or without grippers. Auxiliary equipment for tight winding of coils before cold rolling is also available if back tension is desired on the first pass.

These mills are now under construction for American Brass Co., Waterbury, Conn.; Weirton Steel Co., Weirton, W. Va.; Miller Co., Meriden, Conn.; Seymour Manufacturing Co., Seymour, Conn.; Thinsheet Metals Co., Waterbury, Conn. and Bridgeport Brass Co., Bridgeport, Conn.

Each unit can be furnished either for one way rolling or for reversing service.



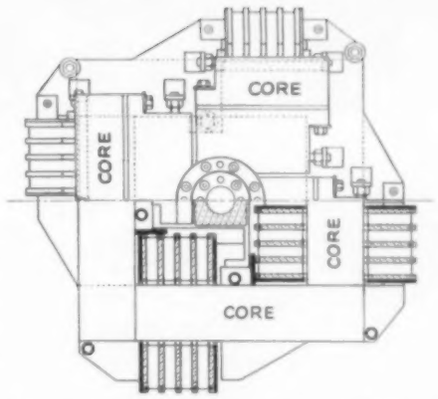
TUBE WELDER

▲ A new tube welder has been perfected by Yoder Co. The most important feature of this welder is the transformer which actually consists of four smaller transformers arranged in somewhat of an offset cross. A single core is enveloped by the four transformers, so that the flux patterns in the four sections are identical. Other than the rear mechanical pads and the common core, the construction of the individual transformers is the same as that of any conventional welding transformer. All secondary paths within the transformer are through continuous copper, a feature not feasible in circular type transformers heretofore in use.

Fundamentally, a welding transformer consists of an iron core, a single turn secondary and a multiple turn primary winding. As the size of the transformer is increased, the primary windings may be placed in series or parallel, as desired, in order to keep the conductor size to an optimum value. However, on the secondary, it being a single turn, there is no choice except as to the number of plates which are to be used in parallel. For practical reasons, the thickness of secondary plates is normally increased as the size or capacity of the transformer goes up.

With this construction in mind, it becomes obvious to the engineer that two factors are affected when the size and spacing of the secondary plates are increased. First, the greater spacing results in higher inductance. Secondly, skin effect (the tendency of alternating current to concentrate toward the outer surface of a conductor) is greater in a single large conductor than in a multiple number of small conductors having an equal total cross-sectional area.

Both of these factors tend to increase the impedance of a transformer so that it becomes highly desirable to keep the plate thickness and spacing between plates to a minimum.



The most important feature of this welder is the transformer which actually consists of four smaller transformers.

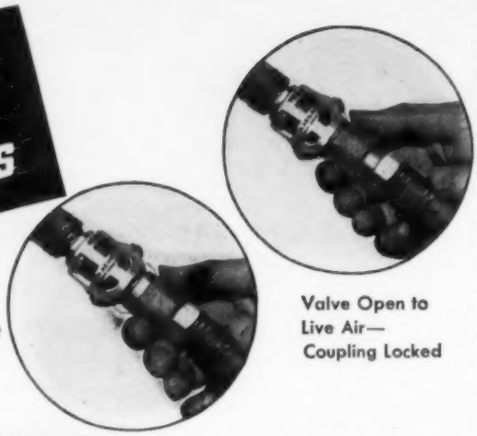
This is accomplished in the new welder by using, instead of one single large transformer unit, four smaller ones. This design reduces the impedance to such an extent that one of the new transformers of, say, 200 kva capacity, will have a percentage of impedance as low as that of a 50-kva transformer of the old type.

The arrangement of the secondary pads is ideal for transferring power through concentric conductors, providing the best electrical and mechanical joint between transformer and secondary conductors, and also allowing very short conductors to the electrodes. This feature contributes further toward high efficiency, at the same time affording greater mechanical strength because of a shorter and more rigid rotating assembly.

To the user of welding equipment, lower impedance may mean two things. First, for a given job, he requires less kva, resulting in lower power costs. Second, and probably more important, he can obtain higher production speeds from a unit of a given capacity rating while staying within the rating of the unit.

Tests made on the new welder show impedance reductions of 15 to 20 per cent compared with the best tube welders heretofore in use. Compared with transformers used in some tube welders, the impedance in the new cross type is from 50 to 60 per cent lower. Accordingly, in the new Yoder complete tube mills, transformer ratios have been changed in order to obtain optimum welding results.

Quick-As-Wink
AIR AND HYDRAULIC
Control Valves



Valve Closed to Live Air— Open to Exhaust

Valve Open to Live Air— Coupling Locked

VALVE COUPLINGS ¼", ⅜", ½", & ¾" SIZES

For Economy and Safety

● These couplings permit air to be shut off and tools changed quickly without going to the main shut-off valve. Coupling jaws are automatically self-locking when valve is open to air supply. The coupling cannot be disconnected until the valve sleeve is moved to closed and exhaust position,— thus preventing accidents and injuries. Pressures to 250 p.s.i.—hose shank, male or female pipe connections. *Send for Bulletin No. 104-C. It gives full details and prices.*

THE HIGHER THE PRESSURE THE TIGHTER THE SEAL

Quick-As-Wink
AIR AND HYDRAULIC
Control Valves

Hand, Foot, Cam, Pilot, Diaphragm and Solenoid Operated

Mfd. by C. B. HUNT & SON, INC., 1986 East Pershing St., Salem, Ohio

ELECTRICAL CONTROL

▲ The basis of the new Sola Electric Co. "Sensivolt" involves a resonant electrical circuit somewhat similar to the constant voltage transformer. One of the applications of this control is in combination with a power relay, and a resistor as a switching device.

The electrical circuit consists of three windings, a primary winding, a secondary winding, and a relay coil winding in series with a capacitor which comprise the resonant circuit. The magnetic circuit consists of a closed core provided with a magnetic shunt.

When low voltage a-c is applied to the primary winding of the transformer, very little of the flux generated cuts the secondary winding, due to the loose coupling. By controlling the reluctance of the magnetic circuit, the voltage of the secondary can be controlled.

As the voltage across the primary is increased, more flux threads the secondary core structures. When this flux density becomes such that the inductive reactance of the secondary winding approaches the capacitive reactance of the capacitor, at the frequency of the exciting voltage, the circuit becomes resonant and the voltages across the secondary winding, and the relay coil rise rapidly to a stable predetermined value. This sudden change in voltage can be caused by as small a change in primary voltage as one-half volt. The rapid change in voltage across the relay coil causes the armature of the relay to close without chatter, and at the same time opens the contacts that have been shorting the resistor. Introducing the resistor into the resonant circuit, however, changes the point at which the primary voltage will cause a sudden decrease in secondary voltage. As a result, for example, the relay can be caused to pull in with 90 volts applied to the primary and drop out at 85 volts. The point at which the secondary voltage suddenly rises with the increase in primary voltage is controlled by the constants of the resonant circuit design. The point at which the relay drops out is controlled largely by the value of the resistor.

Controls can be made for any power system frequency, but it is necessary to have a fixed frequency.

This circuit provides a way for the engineer with a problem of a-c voltage control which is not dependent on vacuum tubes or delicate instrument type relays for the control circuit.

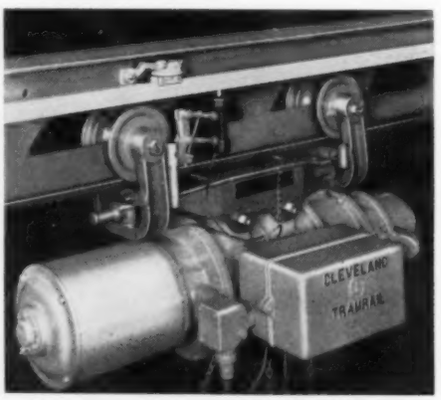
The unit controls electrical machinery by reacting to very slight changes in the voltage of alternating current.

CRANE ELECTRIFICATION

▲ Cleveland Tramrail division of Cleveland Crane & Engineering Co., announce a new type of electrification for overhead cranes and tramrail systems especially designed to provide maximum safety. The development was planned and carried out in anticipation of a possible ruling in the near future by the National Electric Code, making it mandatory to have adequate protection of electrification on overhead materials handling equipment.

The improvement, known as Cleveland Tramrail "Saf-Powr-Bar," consists of inverted U-shaped conductor bars inside of which operate sliding current collector shoes. This electrifi-

This electrification can be applied to overhead cranes.



cation arrangement may be applied to all new Cleveland Tramrail systems, as well as replacement on open-bar electrification. It may also be installed on many hand-propelled systems where motor-powered hoists, carriers, or cranes are now desirable.

Sliding current collector shoes contact three sides of the bar and operate on a pantographic principle. A diagonal spring provides upward pressure on the graphitar shoe while a torsion spring within a plastic housing causes pressure to be applied on both sides of the conductor bar.

1600 FT RAILS

▲ The longest rails in the world from which all clickety-clacks are gone are owned by Elgin, Joliet and Eastern Railway.

These super-long lengths are made by joining together standard 39 ft rail lengths in an automatic oxy-acetylene pressure welding machine. The railroad firm welds together about 40 of the short standard rails which make 1600 ft rails. These are next hauled out on flat cars and laid just like regular rail. Then the long lengths are welded together by a hand

Quick-As-Wink
AIR AND HYDRAULIC
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No. 1491-CS-3
½" 3-Way Solenoid
Operated Air Valve

SOLENOID OPERATED Air Valves

fast, positive, dependable operation

● These valves are widely used for controlling single action air cylinders, clutches, etc. Can be operated with a variety of power switches, mercoid switches or automatic contact switches activated by moving objects. Stainless steel push-pull rods, brass sleeves and U-packings expanded by pressure and all enclosed against dirt, assure long, efficient, trouble-free operation. No metal to metal seating. Precision made. Individually tested. Spring or double solenoid return. ⅜" to 1½" sizes: 2-way, 3-way and 4-way actions. *Write for full details.*

THE HIGHER THE PRESSURE THE TIGHTER THE SEALS

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Mfd. by C. B. HUNT & SON, INC., 1984 East Pershing St., Salem, Ohio

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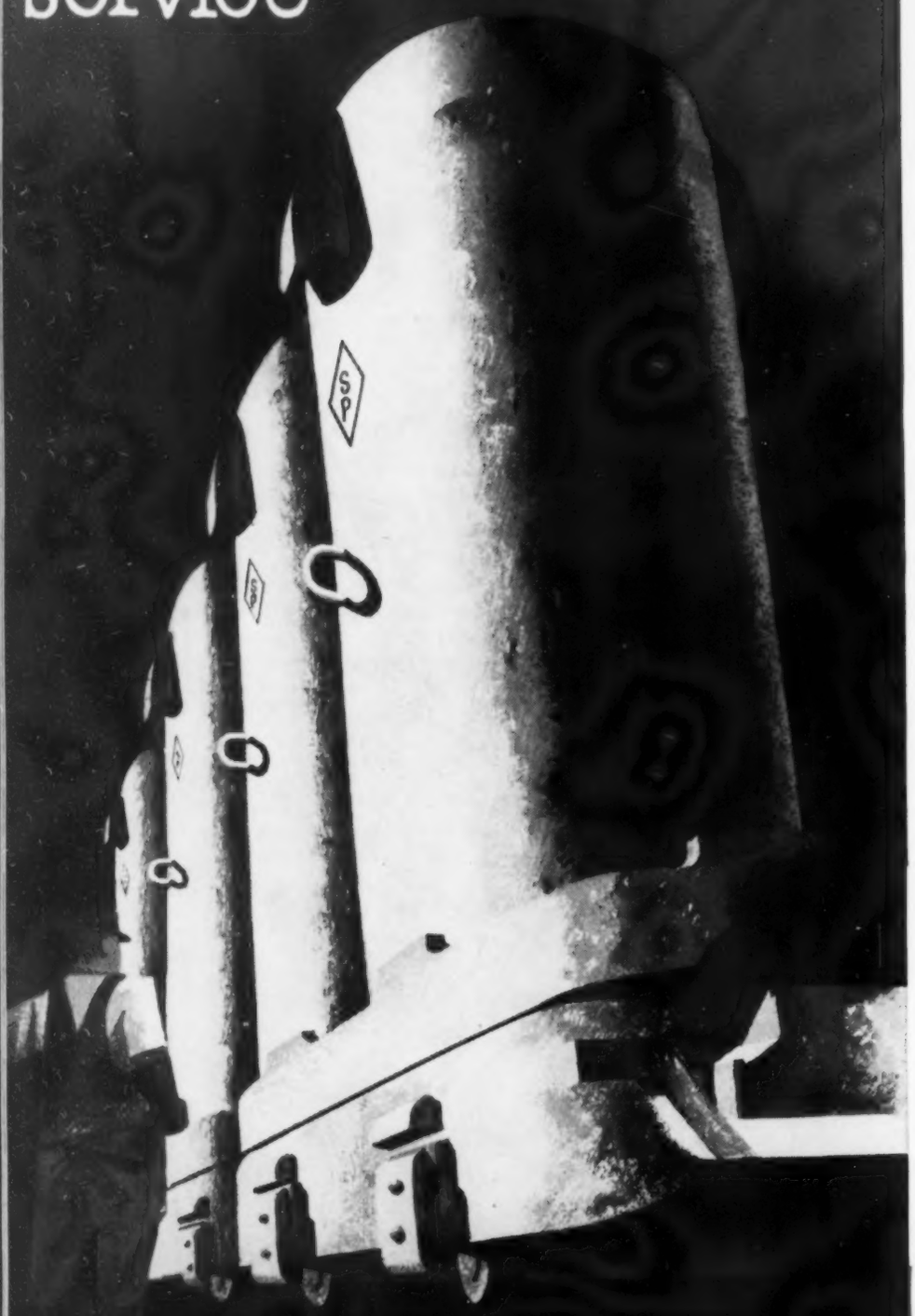


three priceless assets
behind every
SHENANGO·PENN MOLD
SHENANGO-PENN MOLD COMPANY OLIVER BUILDING PITTSBURGH, PENNA.

Crane users should be interested in these long rails.

method to form longer rails thousands of feet in length.

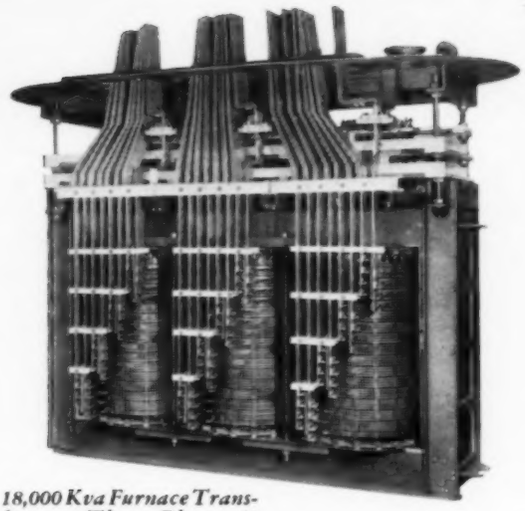
The long rails do not present expansion and contraction problems as continuous rail is laid when the temperature is not too hot or too cold. The enormous friction between rail and the ties tends to overcome expansion. This frictional resistance is increased by the spikes which hold the rail down. Anchors of one type or another are applied to the rail at particular points to prevent its movement. All these factors combined prevent any movement whatsoever in these super-lengths of continuous rail.

WEIGHING DEVICE

▲ A 75 per cent reduction in the time required to weigh 5-ton rod loads in process in the mill is claimed by Riverside Metal Co. The company, which requires the weight information in computing payroll and production data, reports the saving as due to the installation of a 20,000 lb capacity dial-reading scale, hung to the mill crane.

Built to Riverside's specifications by Hydroway Scales, Inc., the device is simply hooked below the lower block by the oval eye built into the scale body. Normally the unit remains slung in this position throughout a work shift, and tackle around the rod loads is made fast in the conventional manner to the hook extending below the scale.

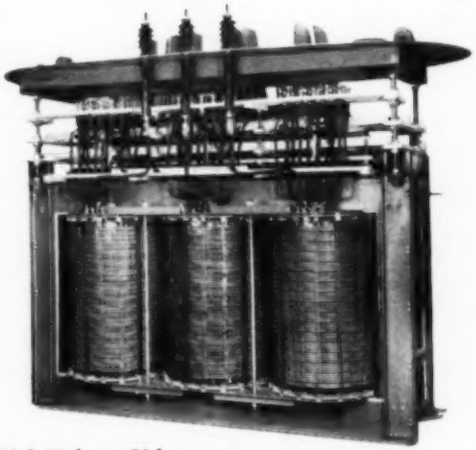
Load weighing previously took five minutes and usually required the attention of three men, plus a foreman who recorded scale readings. Moreover, loads to be weighed had to be lifted clear of obstructions, trans-



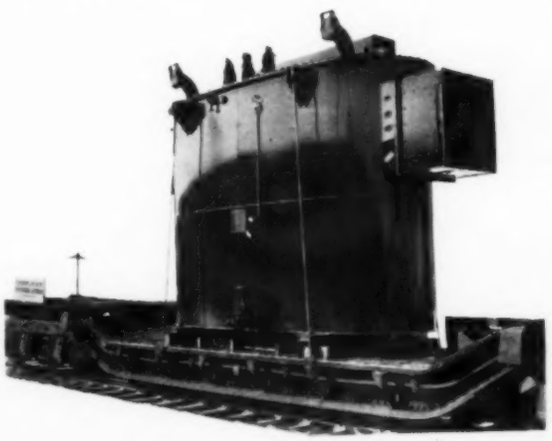
18,000 Kva Furnace Transformer, Three Phase, 60 Cycles, 55°C. Rise, Low Voltage Side

★ The transformer that supplies power to an electric furnace is an extremely complicated unit. The rules governing designs and construction of Power Transformers do not apply to Furnace Transformers. Many special conditions such as overloads, short circuit stresses, distribution of currents and reduction of eddy losses must be met by engineering skill and highly perfected workmanship.

Furnace Transformer FACTS



High Voltage Side



Completed Transformer ready for shipment

1 Overloads & Short Circuit Stresses

Electric Furnace operation inherently subjects Furnace Transformers to frequent short circuits and heavy overloads. The effect of this on the transformer is complicated by the wide range of voltages which necessitates cutting out large portions of the primary windings. The effects of both the radial and axial short circuit forces are greatly reduced in Pennsylvania Furnace Transformers by the use of Circular Coils and an ingenious winding arrangement.

2 Balancing of Stresses

Pennsylvania coils are balanced to reduce the radial and axial short circuit stresses to a minimum. **1.** The circular shape protects the coils against deformation due to radial short circuit forces. **2.** The total axial short circuit force is calculated for each design and the coils are subjected to an equivalent pressure in an hydraulic press. The ability of the coils to maintain their shape, under the prescribed pressure, guarantees that the transformer will safely withstand short circuits.

3 Distribution of Currents

Due to the heavy secondary currents, the winding must be subdivided into numerous parallel sections. A unique arrangement of the windings insures that each section carries an equal share of the current.

Careful transposition of the individual conductors of each section in the windings reduces the copper eddy losses to a minimum. This results in improved efficiency, more uniform copper temperature and prevention of hot spots.

Pennsylvania TRANSFORMERS

Furnace Transformer Experts

Pennsylvania TRANSFORMER COMPANY

CANONSBURG, PENNSYLVANIA

Greater Pittsburgh District

WORKS WHERE OTHERS WON'T

accurately formed

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SPECIFY GRAPHALLOY TRADE MARK REG. U. S. PAT. OFF. WITH CONFIDENCE

SELF-LUBRICATING ● EXTREMELY DURABLE ● CONSTANT CO-EFFICIENT OF FRICTION ● OPERATES DRY — OR *SUBMERGED IN WATER, GASOLINE OR CORROSIVE LIQUIDS* ● APPLICABLE OVER A WIDE TEMPERATURE RANGE — *oven where oil solidifies or carbonizes* ● EXCELLENT AS A CURRENT-CARRYING BEARING.

GRAPHITE METALLIZING CORPORATION

1005 NEPPERHAN AVENUE, YONKERS 3, NEW YORK

ported across the main bay to a floor scale, lowered onto a raised wood table (constructed on the scale to prevent long rods from touching the floor on either side), then weighed, and finally returned across the mill again to the next operation.

The crane-slung scale now permits one man, the crane operator, to observe and record all scale readings on loads while they are in transit, and cuts unproductive weighing-time to between a minute and a minute and a half per load.

When not in use for an extended period, as between shifts, the device is unhooked from the crane and placed conveniently to one side in its own specially designed cradle. The cradle, arc-welded throughout, is constructed of one-quarter and one-eighth inch steel plate and is mounted on castors for easier moving on the mill floor. It is so designed that when the scale is resting in it, the comparatively fragile dial face is tilted away from the cradle back piece, reducing the likelihood of scuffing or possible breaking of the glass.

ABRASIVE BLADE

▲ The new Clipper "B-R" (break-resistant) abrasive blade is one of the most amazing blade products ever produced in masonry cutting. Dropping—twisting in the cut—or bending will not damage this new blade.

It is manufactured in layers of glass fiber cloth impregnated with resins and silicon carbide. This material is then pressed together under hydraulic pressure and processed in kilns where the temperature is scientifically controlled to insure a resilient and tough blade able to take amazing punishment.

Its most effective performance is in the softer range of materials such as limestone, sandstone, light aggregate concrete products and dry press refractories, etc. For harder materials, Clipper metal bonded diamond blades are recommended.

The new blade gives outstanding efficiency on small hand-power tools where it is impossible to maintain a true cutting level. This condition causes the blade to bend or twist in the cut resulting in breakage with the ordinary abrasive blade.

The new blade gives outstanding efficiency on small hand-power tools.

IMMERSION THERMOCOUPLE

▲ Where shop men prefer a thermocouple pyrometer to measure steel bath temperatures in open hearths or electric furnaces, the new immersion thermocouple equipment just announced by Leeds & Northrup Co. offers exceptional operating convenience. The equipment consists of a platinum — platinum 10 per cent rhodium immersion couple and a "Speedomax" pyrometer with special signaling features.

The thermocouple is mounted in a refractory-protected tube, supplied in lengths from five to twelve feet. Routine maintenance can be performed by the operator right at the furnace. The fused silica protective tip can be replaced in a few seconds. A reserve supply of platinum wires is located in the tube. To replace the element, the operator loosens two clamps, pulls out wire for a new junction, and replaces the refractory tip, all without disassembling the unit.

Platinum wires extend all the way to the cold end of the tube. Heating of the tube during immersion does not cause cold junction error. There is no need to allow the tube to cool between measurements.

The recorder operates a set of three signal lights, usually located near the furnace. The green light stays on as long as the thermocouple circuit is closed. The amber light, which comes on whenever the recorder pen moves upscale, shows that the couple is in operating condition. The red signal indicates when the couple registers actual bath temperature; it tells the operator when to withdraw the couple, without need for him to watch the pyrometer's record.

Speedomax range, 2400 to 3200 F, spans the usual steel temperatures. A

separate section at the left edge of the chart covers 0 to 200 F, affording a ready check on room temperature to show thermocouple condition. The recorder keeps itself at full accuracy regardless of wide changes in shop temperature, by automatically standardizing its potentiometer circuit whenever the thermocouple is connected.

SHIPMENTS FOR FAIRLESS

▲ Westinghouse Electric Corp. already has begun shipment of electrical equipment valued at many millions of dollars to the new Fairless works of the United States Steel Co. The order is one of the largest single orders ever placed by a steel mill for electrical equipment.

The ultra-modern mill, located at Morrisville, Pa., will produce an estimated 1,800,000 tons of ingots annually, which will be converted into sheet steel, seamless tube, steel bars, and other products.

In addition to motors, control and regulating equipment, generators and switchgear, the order provides for the largest air-cleaning and ventilating system in the industry, special fans and precipitron air cleaners will move and clean more than three and one-half million cubic feet of air per minute.

Also included in the multi-million-dollar order are outdoor substations, with a transformer capacity exceeding 300,000 kva.

A double-armature twin drive totaling 12,000 hp will be used for the main drive of the 45-in. slabbing mill, and a 4000-hp motor will be used for the edging rolls. A motor-generator set with a 13,500-kw capacity will supply power for the combined drives.

The motor-generator set will be equipped with a 65-ton flywheel, having a stored-energy of 215,000 hp seconds.

Westinghouse also will supply both the adjustable- and constant-voltage controls for this slabbing mill, and auxiliary motors totaling 6500 hp.

Two 4000-hp motors, with a 7500-kw motor-generator set, will furnish power for the main drive of the 40-in. blooming mill, and a 3600-hp motor will power the main drive of the 80-in. skin-pass mill.

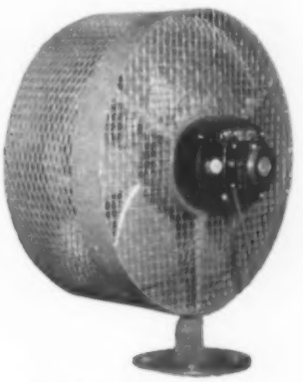
Five 5000-horsepower motors and one 4000-hp motor will be supplied d-c by ignitron rectifiers for the finishing end of the hot strip mill.

X-RAY MEASUREMENT

▲ Use of X-rays to give its customers accurately measured electrolytic and hot-dipped tinplate, is the latest innovation to be adopted by the Weirton Steel Co. The company will soon be prepared to place in operation the new X-ray method of measuring the amount of tin on all products manufactured by the company.

Measurements of hot and cold rolled strip thickness, continuously on the mill without touching the strip, is now being accomplished in the Weirton plants by passing the X-rays through the metal. The portion of these invisible rays that gets through the strip is used as a measure of the thickness. This method of measuring thickness results in more accurate control of the gage of hot strip, higher

IS HEAT SLOWING UP YOUR WORKMEN?



TRUFLO CRANE CAB FANS
For cooling interiors of crane cabs and other confined areas. Adjustable both horizontally and vertically. Four blade type, 12 and 18 in. sizes.

Keep them COOL with TRUFLO FANS

TRUFLO PORTABLE COOLING FANS
Easily portable. Help keep efficiency high where work is hottest. 12 to 36 inch diameters.

Production suffers when workmen are overheated. Steps begin to drag, efficiency falls.

Now, when speedy production is vital, Truflo Fans can help keep your workmen on their toes. All Truflo Fans are designed and built correctly to put fresh cool air *in large volumes* exactly where it is needed. Perfectly-balanced shafts and blades give more air per h.p. . . . strong steel frames stand up longer under hard use . . . rugged wire guards protect men against injuries.

All of the following types can help beat the heat, keep production moving in your plant. Write for illustrated literature.

PORTABLE COOLING FANS
CRANE CAB FANS • WALL FANS
EXHAUST FANS • BLOWERS
ROOF VENTILATING FANS
PENT HOUSE FANS

TRUFLO FAN COMPANY

245 MAIN ST., HARMONY, PA.

rolling speeds on cold mills and other improvements over using mechanical measuring devices which must make contact with the metal.

The non-contacting radiation gages are gradually becoming standard in steel plants for the accurate measurement of strip thickness. Once such radiation gages were successfully placed in operation in the hot and cold strip steel departments, the Weirton scientists investigated use of X-ray measurements for controlling the thickness of coatings of Weirton's principal product, electrolytic and hot-dipped tin plate.

This development has followed closely on the astounding announcement of a few months ago that Weirton Steel had developed a new revolutionary electrolytic tinplating process that saves 25 to 50 per cent of strategic tin now so vitally needed for national defense.

Under this revolutionary method, Weirton tinplate is plated on one side with the amount of tin coating necessary to protect the contents of the tin can, and on the other side with only the amount of tin coating needed to protect the outside of the can from exposure.

ROTARY STRAIGHTENERS

▲ Downtime in seamless tube manufacture at the No. 3 hot mill in the Allenport, Pa. plant of Pittsburgh Steel Co. has been minimized through a program of alternating the use of two rotary straighteners.

The company owns two "Model A-3" straighteners made by Mackintosh-Hemphill Co. While one machine is in the production line, between cooling table and cut-off unit, the other straightener is at the maintenance shop receiving a major overhaul.

General renovation at this mill takes place at approximately two year intervals. When this is due, a switch of the machines can be made in three or four days downtime, instead of 7-10 days' loss of production if major repairs were to be made on a rotary straightener in the production line.

Both machines remove bends and waves from seamless tubing varying in diameter from 3½ to 8⅝ in. The rotary straighteners also have straightened tube which is 7¼ in. outside diameter with 1¼ in. wall thickness.

COUNTER-BALANCED VAULT

▲ The new Wachs safety counterbalanced vault or manhole cover is designed for safe and easy operation. Opening is accomplished by inserting a combination key-handle and giving it a half turn. Lifting the cover to its vertical open position is a one-handed job because counterweights, which also hold the cover in a protective upright position, ease the load.

Other features of this safety vault cover are — one man can safely raise cover with ease — cover cannot slam or drop into vault to cause injury or damage — cover can be opened from inside of the vault by one man — positive tamper proof lock that cannot be opened without key-handle — counterbalance structure protrudes less than 6 in. from wall.

Here's an installation of a 4-High High Speed Rolling Mill for Strip and Foil built by Loewy Rolling Mill Division, Hydropress, Inc., properly equipped with STEARNS Magnetic Disc Brakes.

Quickly stopping the adjusting screws on this Loewy High Speed Rolling Mill is everyday work for STEARNS Magnetic Disc Brakes. Designed with a quick, steady pressure that brings a fast stop in the shortest time, STEARNS Magnetic Disc Brakes prevent overtravel of the adjusting screws and thus allow for careful, positive adjustment. Suitable for horizontal or vertical applications, STEARNS brakes are available in sizes up to torques of 575 pounds feet.

What is your overtravel problem? Give us the details; we'll forward recommendations without obligation. Remember, there's a STEARNS EXPERIENCE ENGINEERED unit for your screwdown requirements.

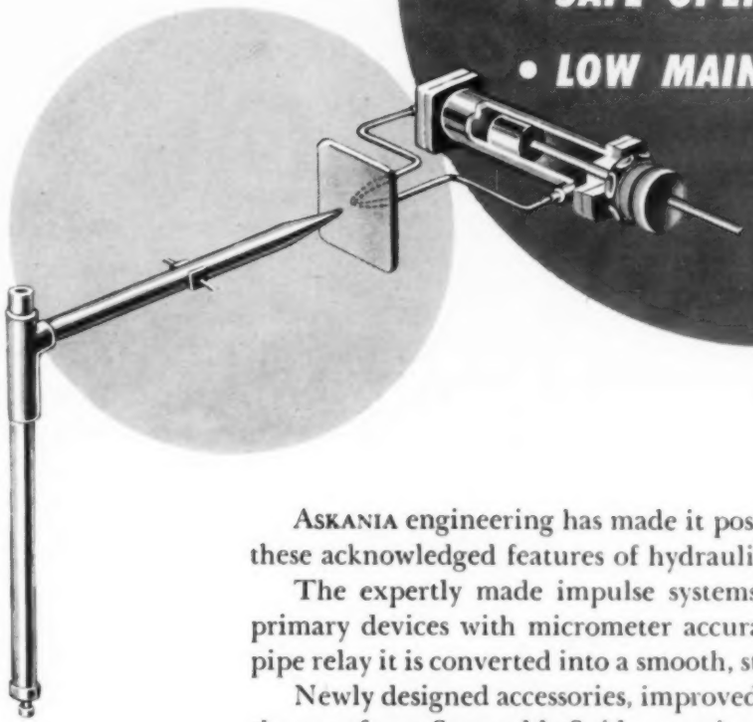
Stearns MAGNETIC MANUFACTURING CO.

681 S. 28th St., Milwaukee 46, Wisconsin

ASKANIA HYDRAULIC CONTROLS

Features:

- ACCURATE MEASURING DEVICES
- POSITIVE ACTION
- SAFE OPERATION
- LOW MAINTENANCE



ASKANIA engineering has made it possible for Industry to appreciate these acknowledged features of hydraulic control.

The expertly made impulse systems measure the signal from the primary devices with micrometer accuracy. Through the exclusive jet pipe relay it is converted into a smooth, stepless, positive hydraulic force.

Newly designed accessories, improved fittings, and construction, plus the use of non-flammable fluids, permit use of Askania hydraulic control even in hazardous locations, corrosive or dirty atmospheres and low temperatures.

ASKANIA hydraulic controls have operated perfectly for years without maintenance or repair. The hydraulic fluid provides continuous lubrication and there are no minute clearances or delicate adjustments required for the jet pipe relay to function continuously.

The simple operating principles of Askania hydraulic controls and their construction permit assembly after inspection, when necessary on the job, with a minimum of down time.

ASKANIA Controls

ASKANIA REGULATOR COMPANY

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

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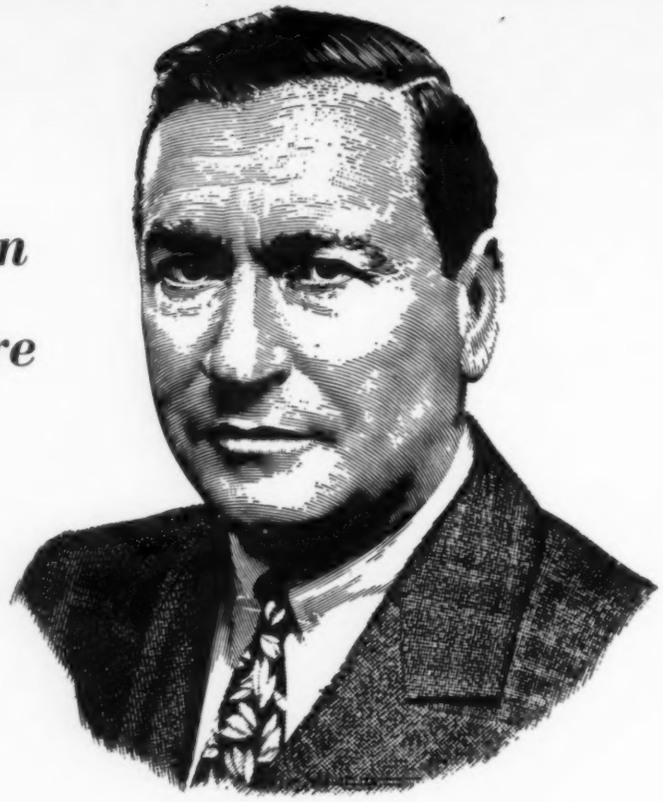
"You Build for your own and your country's future when you save..."



BENJAMIN F. FAIRLESS

President, U. S. Steel Corporation

"A free economy, such as ours, is built on the savings of the people. And the future security of America depends on the initiative and the growth of every citizen. We in U. S. Steel encourage our employees to join the Payroll Savings Plan, and we are proud that the National Tube Company, one of our subsidiaries, was the first of the large industrial companies of the nation in 1950 to have more than 80% of its employees participating. Remember, you build for your own and your country's future when you save."

Mr. Fairless is not expressing a personal opinion, nor is he speaking for other far-seeing executives when he tells you that our economy is built on the savings of the people and a man builds for his own and his country's future when he saves.

Actually, Mr. Fairless is merely putting in words the thoughts and action of the millions of employed men and women who *now hold* more than 50 billion dollars in U.S. Savings Bonds.

$50,000,000,000! Who *sold* all those bonds to millions of people? The answer is, nobody sold them.

80% of the employees of the National Tube Company ... 75% of the employees of Carnegie-Illinois Steel Company ... thousands of employees of other U.S. Steel subsidiaries ... more than 8 million employees of other companies bought U.S. Savings Bonds and are buying them every month on the easy, automatic Payroll Savings Plan. Their employers merely offered these men and women an opportunity to save for their future. There was no pressure, no emotional appeal.

How does employee participation in *your* Payroll Savings Plan match up with the 80% of National Tube, the 75% of Carnegie-Illinois? Or, perhaps you are one of the relatively few large companies that do not have a Plan? In either case, wire or write, Savings Bond Division, U.S. Treasury Department, Suite 700, Washington Bldg., Washington, D.C. Your State Director is ready to help you with a package plan—application blanks, promotional material, practical suggestions and all the personal assistance you may desire.

The U. S. Government does not pay for this advertising. The Treasury Department thanks, for their patriotic donation, the G. M. Basford Company and

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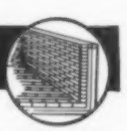
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Book Reviews

▲ **ASTM Standards On Gaseous Fuels,** second edition, prepared by ASTM Committee D-3 on Gaseous Fuels, includes in convenient form for use of industry the seven ASTM standards pertaining to this field. The book represents years of research involving basic considerations, the types of instruments suitable for measurements required and for reproducibility, and a host of other problems. The contents cover sampling and measurement, and methods of testing and analysis.

Copies of this 144-page publication, heavy paper cover, can be procured from American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., at $1.75 each.

▲ **Air Conditioning in Summer and Winter,** second edition, by R. E. Holmes provides thorough coverage of equipment and procedures essential to efficient planning, installation and upkeep of air conditioning systems. This practical reference supplies well-illustrated explanations of air conditioning principles and methods and shows how they are applied in everyday practice.

Topics of importance in solving both summer and winter air conditioning problems — the physiology of comfort, phychrometric principles and the kinds of equipment that are available — are discussed first. Next, the special features of winter heating and control are analyzed: how to calculate winter-heating loads, and how to install and maintain appropriate equipment. The author then introduces refrigeration principles and equipment design, points out the differences between summer cooling-load calculations and winter heating-load calculations, and describes typical installations. Throughout the book the latest in commercially available equipment — panel heating systems, electrostatic air cleaners, heat pumps, packaged air conditioners, absorbent and adsorbent dehumidifiers, etc. — is illustrated and explained.

Before becoming associated with the Worthington Pump and Machinery Corp., R. E. Holmes devoted 17 years to the design of air conditioning equipment at Westinghouse. The price of this book is $5.75. It may be obtained from McGraw-Hill Book Co., 327 W. 41st St., New York 18, N. Y.

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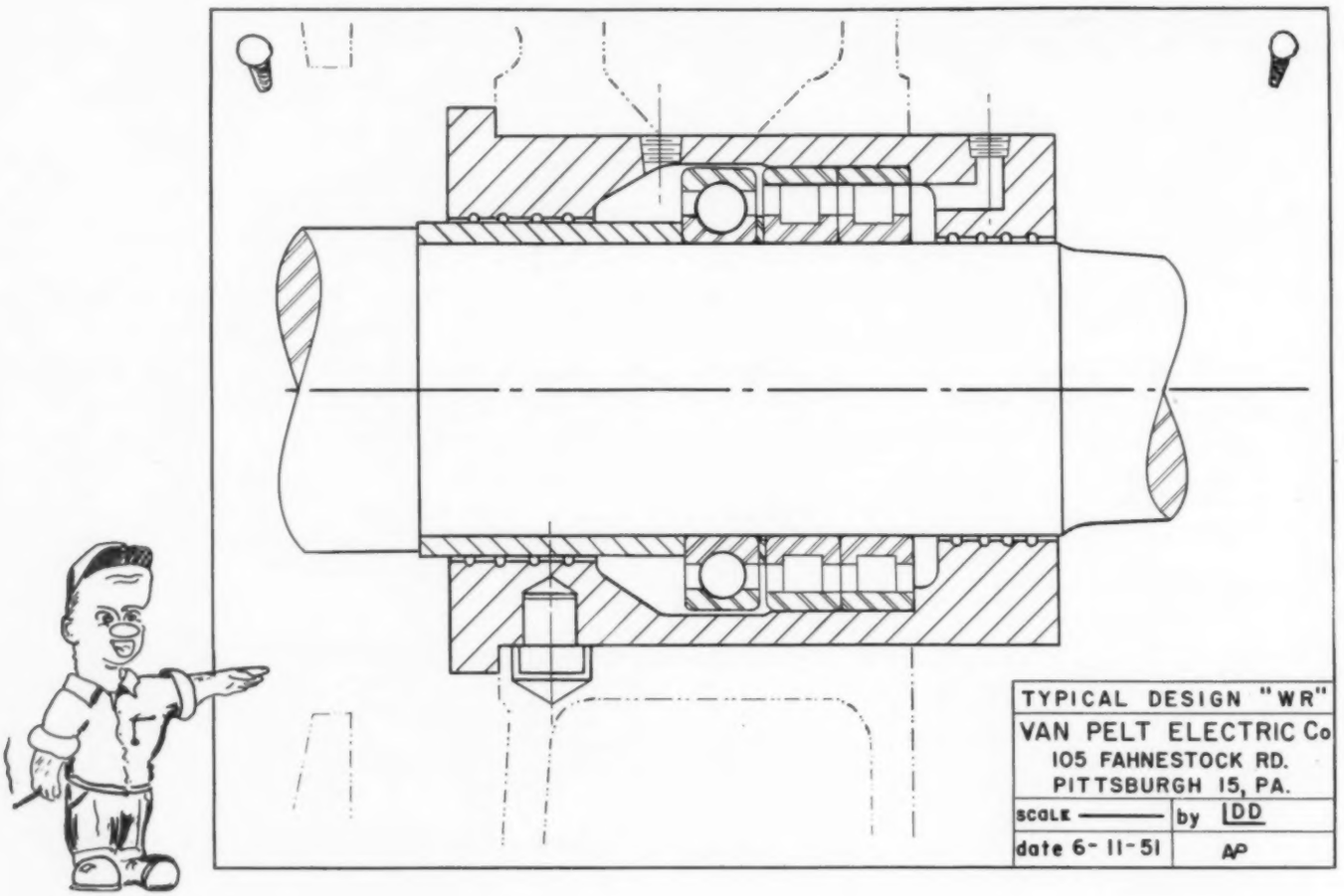

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"My mill lost lotsa' money for years every time one of the old sleeve bearings failed 'til we gave those Van Pelt Motor Changeovers a try. Biggest doggone money saver we ever had. They've got changeovers for all your other mill and crane motors too. You ought to try some."

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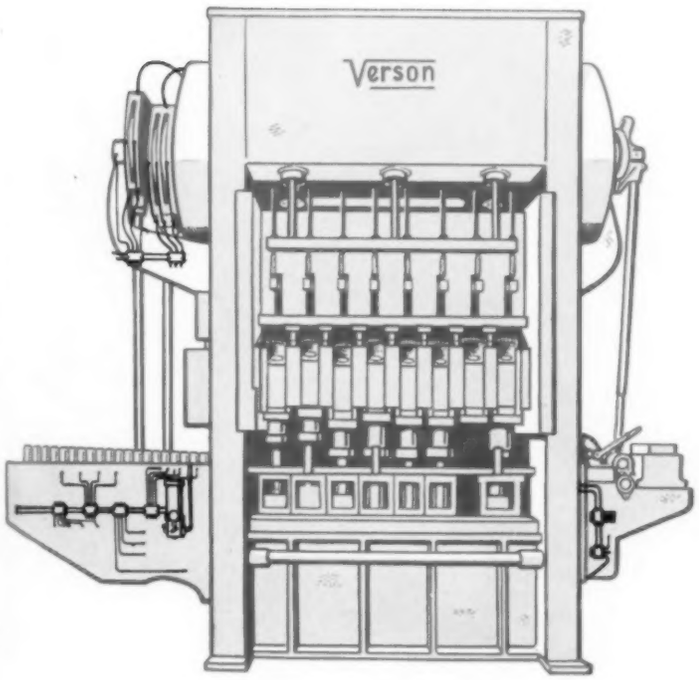
30 million stampings without a bearing failure

...thanks to Farval lubrication

FARVAL—*Studies in Centralized Lubrication* No. 123



With a few strokes of the Farval hand lever, every bearing of this big Verson Transmat Press is adequately lubricated. No stopping the machine, no time lost, and never a bearing missed.

VERSON built and installed this high-speed Transmat Press in a metal-working plant in 1946. It was factory-equipped with a Farval system of Centralized Lubrication. In the five years since its installation, the machine has never been shut down for lubrication, for bearing replacement, or, in fact, for anything other than ordinary preventive maintenance.

The press is used for progressive dieing. Coil stock is fed into the blanking station and then carried by a finger feed for several succeeding operations. It works at the rate of 22 strokes per minute. In continuous operation for five years, this press has turned out in excess of 30,000,000 stampings. By eliminating down time for lubrication and repair or replacement of bearings, Farval has contributed importantly to this impressive output—and should continue to do so for years to come.

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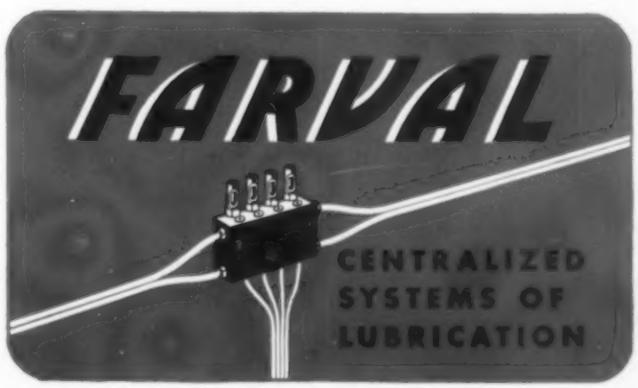
For a full description of Farval, write for Bulletin 25. The Farval Corporation, 3278 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.



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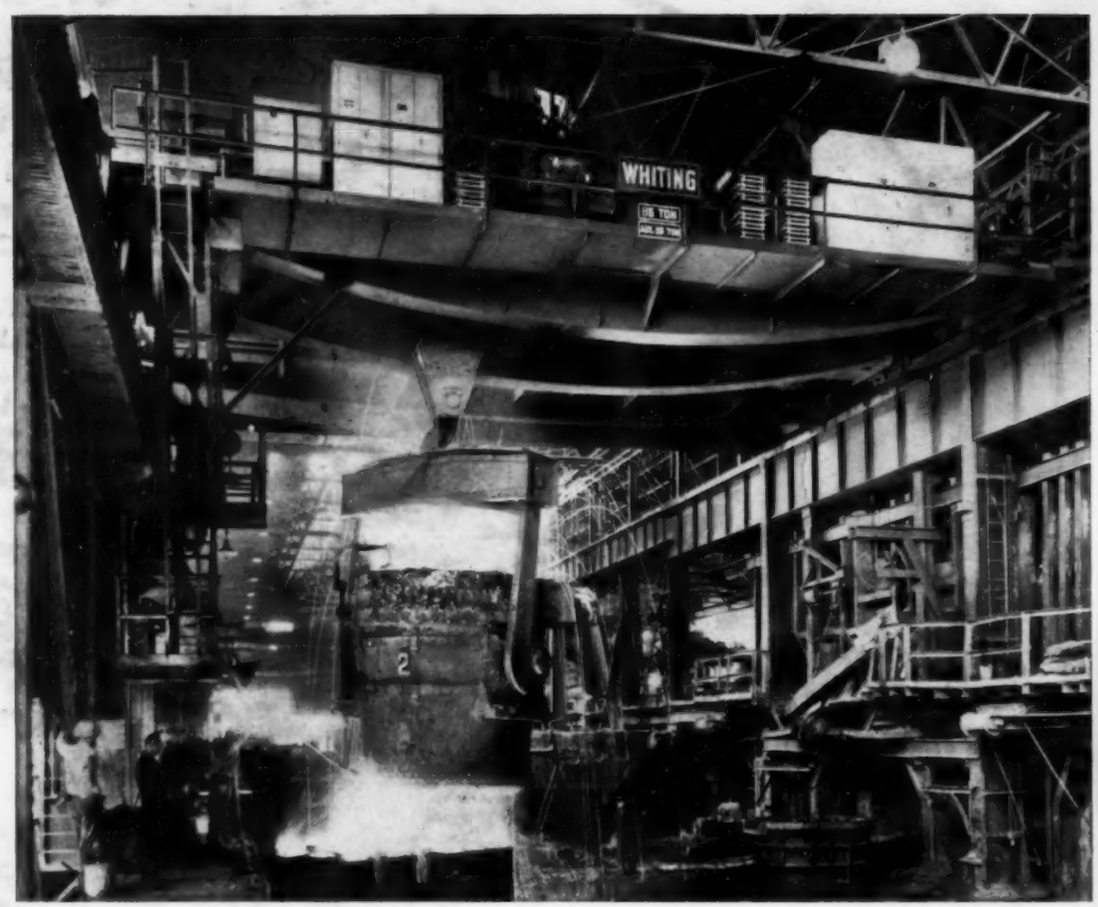
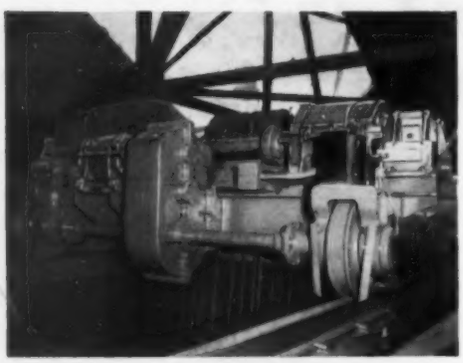
Teeming is easy with new G-E d-c control which permits faster, more accurate positioning because of slow first-point lowering, no downward drift on first hoisting point.



"Heats" poured faster!

New G-E crane-hoist control—teamed with heavy-duty motors and fast-acting brake—permits safer, more accurate handling of new 115-ton ladle crane



Close-up of main trolley shows (at right) the 65-hp main hoist motor with newly designed G-E d-c magnetic brake for quick, accurate stops. At left is the 19-hp G-E trolley motor. Both motors are MD-600's—toughest G-E mill motors ever built.

Providing safer, more accurate control of this 115-ton ladle crane is the new G-E d-c crane control . . . control which has been *job-tested* on more than 50 tough-duty steel-mill installations. Here are a few of its features:

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Whatever *your* crane drive problem, let a G-E steel-mill specialist help you reach a successful solution. For more data on G-E d-c crane drives, send for Bulletin GEA-5408. *General Electric Company, Schenectady 5, N. Y.*

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